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The enhancement of composite scarf joint interface strength through carbon nanotube reinforcement

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THESIS

THE ENHANCEMENT OF COMPOSITE SCARF JOINT INTERFACE STRENGTH THROUGH CARBON NANOTUBE REINFORCEMENT

by

Randolph E. Slaff Jr.

June 2007

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The objective of this research is to investigate the potentially significant improvement to scarf joint bonding achieved through the dispersion of carbon nanotubes along the interface of the composite joint. The study examines various factors that may affect carbon nanotube reinforced joint interface strength. Each composite joint consists of a vinyl-ester matrix base, DERAKANE 510-A, interlaced with a carbon fiber weave, TORAY T700CF. During the curing process the research explores several variables concerning the carbon nanotube application. The testing includes single walled carbon nanotubes (SWCNT) and multi-walled carbon nanotubes (MWCNT) with varying length, purity, and concentration levels along the surface area of the joint interface. This wide array of data demonstrates the effect of carbon nanotubes introduction at the joint interface and provides the ideal type, size, purity level, and concentration level for composite scarf joint bond reinforcement using carbon nanotubes.

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THE ENHANCEMENT OF COMPOSITE SCARF JOINT INTERFACE STRENGTH THROUGH CARBON NANOTUBE REINFORCEMENT

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Submitted in partial fulfillment of the
requirements for the degree of

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The objective of this research is to investigate the potentially significant improvement to scarf joint bonding achieved through the dispersion of carbon nanotubes along the interface of the composite joint. The study examines various factors that may affect carbon nanotube reinforced joint interface strength. Each composite joint consists of a vinyl-ester matrix base, DERAKANE 510-A, interlaced with a carbon fiber weave, TORAY T700CF. During the curing process the research explores several variables concerning the carbon nanotube application. The testing includes single walled carbon nanotubes (SWCNT) and multi-walled carbon nanotubes (MWCNT) with varying length, purity, and concentration levels along the surface area of the joint interface. This wide array of data demonstrates the effect of carbon nanotubes introduction at the joint interface and provides the ideal type, size, purity level, and concentration level for composite scarf joint bond reinforcement using carbon nanotubes.

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I would also like to thank the Naval Surface Warfare Center (NSWC) and the Naval Postgraduate School (NPS). NSWC provided NPS with materials and financial support required for composite construction. NPS provided the facilities and test equipment needed to conduct this research.

Finally, I would like to thank my wife, Maraya, and my son, Nicholas, for their patience and encouragement. Their understanding and support enabled me to focus on my research and ultimately complete this thesis.

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I. INTRODUCTION

A. BACKGROUND

Modern ship construction is continually gravitating towards composite structures that ideally reduce weight without sacrificing strength. The United States Navy’s endeavor to construct the entire superstructure of the next generation destroyer solely of composites, has given rise to many questions regarding joint strength at composite interfaces. The composites themselves are sufficiently strong [1]. However, there are inherent weaknesses present at adjoining sections due to the break in continuity of fibrous material. At these joints the structures are more susceptible to failure caused by delamination. The joint interface lacks the strength characteristics possessed by the remainder of the composite section. It is this discontinuity in fibrous material that deprives the structure of the additional strength characteristics attributed to the fiber. The question is, since there is no easy way to avoid the fiber discontinuity, how can the strength of the joint be enhanced enough to consistently support loaded conditions?

The emergence of the carbon nanotube (CNT) and the benefits of its properties have opened many possibilities for structural enhancement. For over a decade, the primary research in this area has dealt with nanotube inclusion directly into composite material. This still presents a problem of a weak interface between two joined structures. There has also been research devoted to the application of a conglomeration of epoxy resin/multi-walled carbon nanotube adhesives to join graphite reinforced polymer

composites. To build on this idea of improving joint strength via carbon nanotube inclusion, this research investigates the benefits of introducing the carbon nanotubes along the surface interface prior to the bonding of two composite structures.

B. LITERATURE SURVEY

The elastic modulus of carbon nanotubes is greater than one TPa, which is 10 to 100 times stronger than the strongest steels, with tremendous reductions in weight [2]. This attribute possessed by CNTs has made them extremely desirable for use in composite reinforcement. Countless studies have been performed using carbon nanotubes to reinforce different matrix materials including ceramics, metals, and polymers. In some studies, different types of CNTs were tested in the same polymer matrix. One study documented the use of several different types of carbon nanotubes in a polymer composite, yielding a two fold increase in Young’s modulus. The same study indicated that low diameter multi-walled carbon nanotubes were the ideal CNT for reinforcement due to their surface area characteristics [3].

Improvements in stiffness and strength, through the inclusion of CNTs, have been proven over and over again. The general conclusion is that in order to harness the strength characteristics of the CNT, CNT/matrix wetting, adhesion, and uniform CNT dispersion are of extreme importance. Wetting and adhesion are most important because in order for the reinforcement to be effective, strong interfacial bonding must be present [4]. Wettability is the ability of the composite matrix to contact the surface of the reinforcement. The interfacial bonding will provoke

load transfer between CNTs and polymers. With load transfer being imperative to the success of strength enhancements, numerous studies have been performed to analyze the CNT polymer interface. Micromechanical interlocking, chemical bonding, and van der Waals bonding between the fiber and the matrix are the three mechanisms of load transfer. With van der Waals bonding being weak and micromechanical interlocking being improbable due to the CNT’s inherent smooth surface, chemical bonding is the most influential mechanism in nanotube load transfer [5]. Following this observation, studies were performed in attempts to quantify the chemical bonding [6]. These studies support the chemical bonding hypothesis which explains the interfacial bonding strength and ultimately helps to gain understanding as to why carbon nanotube reinforcement of polymers is generally a success [7]. Figure 1 shows various CNT pullout positions as the polymer fractures. It also shows the crack bridging of CNTs following crack initiation.

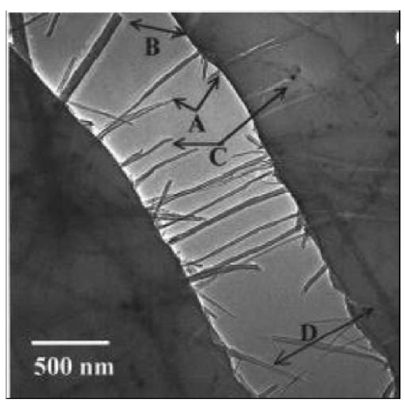

Figure 1. Failure of Nanotube Composite (From Ref. [8])

The topic of the present research is not to investigate interfacial bonding strength or the strength improvements of CNT reinforced composites. Those topics have been investigated thoroughly and proven positive. This

study builds off of the already known CNT-polymer strength enhancements in an attempt to improve acceptability for the United States Navy. The expense of carbon nanotubes make them impractical for many naval construction applications. However, if they could be used in a local application to improve the weakest points in a composite structure, then the Navy could reinforce the structural weak points without the added expense of dispersing nanotubes throughout the matrix. This study explores the possibility of localized reinforcement of a weak point, the scarf joint, in order to prove that CNTs can reinforce isolated positions without conventional dispersion methods.

C. OBJECTIVES

The objective of this research is to assist the Naval Surface Warfare Center Carderock Division (NSWCCD) team for “Advanced Hull Materials & Structures Technology (AHM&ST)”, particularly in the technology area of bonded composite joints. Specifically, the work investigates the potentially significant improvement to composite scarf joint bonding by dispersing carbon nanotubes at the interface between the two composite structures.

The research goal is to investigate the effect carbon nanotube dispersion along the joint interface has on scarf joint strength. The study examines various factors that can affect joint strength along with carbon nanotubes. The study focuses on determining the optimal parameters to improve the interface strength significantly.

The wide array of testing is intended to conclusively demonstrate the effect of the introduction of carbon nanotubes to the interface of a composite joint. If there is a substantial increase in joint strength, it should be

definitively related to several variables. The variables include, carbon nanotube dispersing agent, types of carbon nanotubes (single-wall or multi-wall), length of nanotubes, diameter of multi-walled carbon nanotubes, and concentration of nanotubes across the surface of the joint interface.

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II. COMPOSITE CONSTRUCTION AND METHODOLOGY

A. COMPOSITE CONSTRUCTION

The composite test joints were constructed to match, as closely as possible, the composite scarf joints used in today’s ship construction throughout the Navy. The test joints were constructed via a wet vacuum bag layup procedure with an overlap in the joint interface (Method 1). A step-step interface configuration was used due to the ease of carbon nanotube application and to alleviate some of the construction complications [9]. The difference between Method 1 and Method 2 for composite construction is the overlap of the top step. Figure 2 provides an illustration of the different methods.

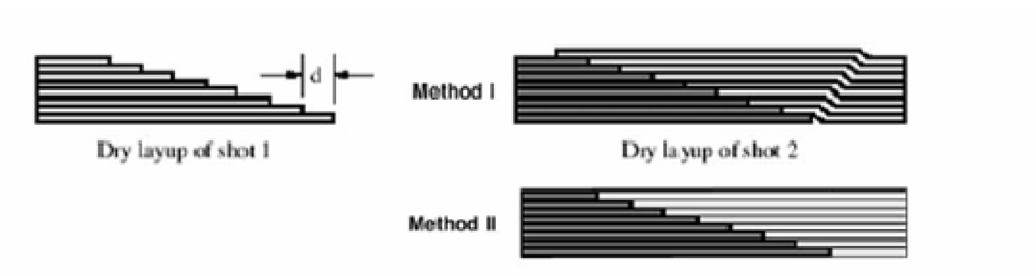


Figure 2. Layup Procedures (From Ref. [10])

Each composite consists of a vinyl-ester matrix base (Derakane 510A) interlaced with carbon fiber (Toray T700 CF). All cases were tested with and without carbon nanotubes at the interface so that an apple-to-apple comparison could be made. A multitude of tests were performed to accommodate many possible parameter variations. After the preparation of each surface the carbon nanotubes were applied before the curing process begins. In order for carbon nanotubes to act as reinforcing

fibers, significant load transfer must exist between the polymer and the nanotube [11]. The interface is strengthened via chemical bonding and has been known to increase the stress transfer in epoxy/nanotube composites to 500MPa. This emphasis on chemical bonding shows a dependence on the curing process. The curing dependence can allow for experimental variations in curing temperatures, etc. The intention of this research is to investigate the reinforcement attributes of both single and multi-walled carbon nanotubes.

1. Material and Chemical Requirements

The material and chemical requirements necessary to mimic the scarf joint construction ongoing at NSWCCD consisted of Derakane 510A vinyl ester resin, Methyl Ethyl Ketone Peroxide (MEKP), Cobalt Naphthenate (CoNap), N-dimthylaniline (DMA), and 300 grams per square meter Toray T700 carbon fiber fabric.

In addition to the composite ingredients, fabrication required aluminum plates, peel ply, porous non-permeable ply, buffer ply, vacuum bags, and a vacuum. The aluminum plates were used as a foundation for building the composite pieces. The peel ply and porous non-permeable plies were used to prevent the resin from sticking to foreign objects such as vacuum bags or aluminum plates. The buffer ply was used to absorb excess resin in an effort to reduce the matrix to reinforcement volume ratio. The vacuum and vacuum bags were used during the curing process to create a negative pressure in order to reduce the number of air pockets throughout the test joint. The vacuum bags had a check valve built in to allow for air removal. This provided a logical attachment position for the vacuum.

a. Chemical Composition of the Matrix

Derakane 510A was used as the base matrix resin throughout the project. MEKP and CoNap were used as hardeners. The amount of hardeners used was varied to achieve the desired gel time of 60 minutes. On rare occasions DMA was included as a hardener depending on ambient temperature.

Normally the ambient temperature remained between 70˚F and 80˚F. To achieve a gel time of 60 minutes for the vinyl ester resin the combination of hardeners consisted of 1.25 %wt MEKP and 0.20 %wt CoNap. If the temperature dipped below 70˚F, then .05 %wt DMA was used to maintain the 60 minute gel time. This was the only case when DMA was used because if the ambient temperature rose above 70˚F the resin would gel too quickly and the process would have to be repeated [12].

b. Reinforcement Characteristics

300 grams per square meter woven Toray T700 carbon fiber fabric was used as the reinforcement material. To prepare the fabric for composite assembly, the fabric was cut into 25.4cm wide sheets. The width was limited to 25.4cm because the width of the aluminum plate which was being used in the fabrication process was only 30.5cm. The sheet length depended on which step it was going to be included.

2. Test Joint Construction Procedures

Once the proper procedure for composite construction was identified, the procedure was standardized to ensure each test sample was constructed in the same fashion. Each sample consisted of 16 plies of Toray T700 carbon fiber that combine to form a four-step interface. Each step

consisted of four plies of carbon fiber fabric. The total thickness of each test joint was approximately 0.9cm. The length of each step was approximately 1.3cm. This generated an overall joint interface of 3.8cm with an overlap of approximately 1.3cm. The resulting aspect ratio, interface length (L) divided by overall thickness (t), was approximately equal to 4.0.

The step by step process has been articulated and illustrated below.

Step 1: Cut 16 sheet of carbon fiber fabric.

4 sheets 25.4cm x 17.2cm

4 sheets 25.4cm x 15.9cm

4 sheets 25.4cm x 14.6cm

4 sheets 25.4cm x 13.3cm

Step 2: Combine chemicals in the order shown below and stir continuously.

412 grams Derakane 510A

5.15 grams MEKP

0.825 grams CoNap

Step 3: Manually apply resin compound to each sheet of carbon fiber fabric using a brush. A layer of porous non-permeable ply and peel ply should be spread across the aluminum plates prior to composite layup.

Step 4: While applying the resin to the reinforcement, be sure to align sheets to produce four steps with an individual step interface length of 1.3cm.

Step 5: Immediately following the completion of the 16 ply layup, the composite should be wrapped in one layer of peel ply, followed by one layer of porous non-permeable ply, followed by one layer of buffer ply.

Step 6: After the application of the various plies, the plate should be placed inside the vacuum bag. Seal the bag and ensure that it is airtight.

Step 7: Connect the vacuum to the bag and turn the vacuum on. This removes the excess air in the bag and reduces the trapped air in the composite structure. The negative pressure created by the vacuum also promotes the removal of excess resin which is consequently absorbed by the buffer ply.

Step 8: After eight hours of curing, turn off the vacuum, remove aluminum plate from the bag, and remove the top plies. Half of the test joint plate has been constructed.

Step 9: Repeat Step 1 through Step 7 along the step interface of the completed half. Ensure the top four sheets of carbon fiber create an overlap at least 1.3cm in length.

Step 10: After eight hours of curing, remove all plies from the top and bottom of the composite joint plate. The composite plate is now ready for sample preparation.

Sample preparation is discussed in the Experimental Setup and Testing section. The dimensions were chosen to ensure that the test joint do not fail as a result of buckling.

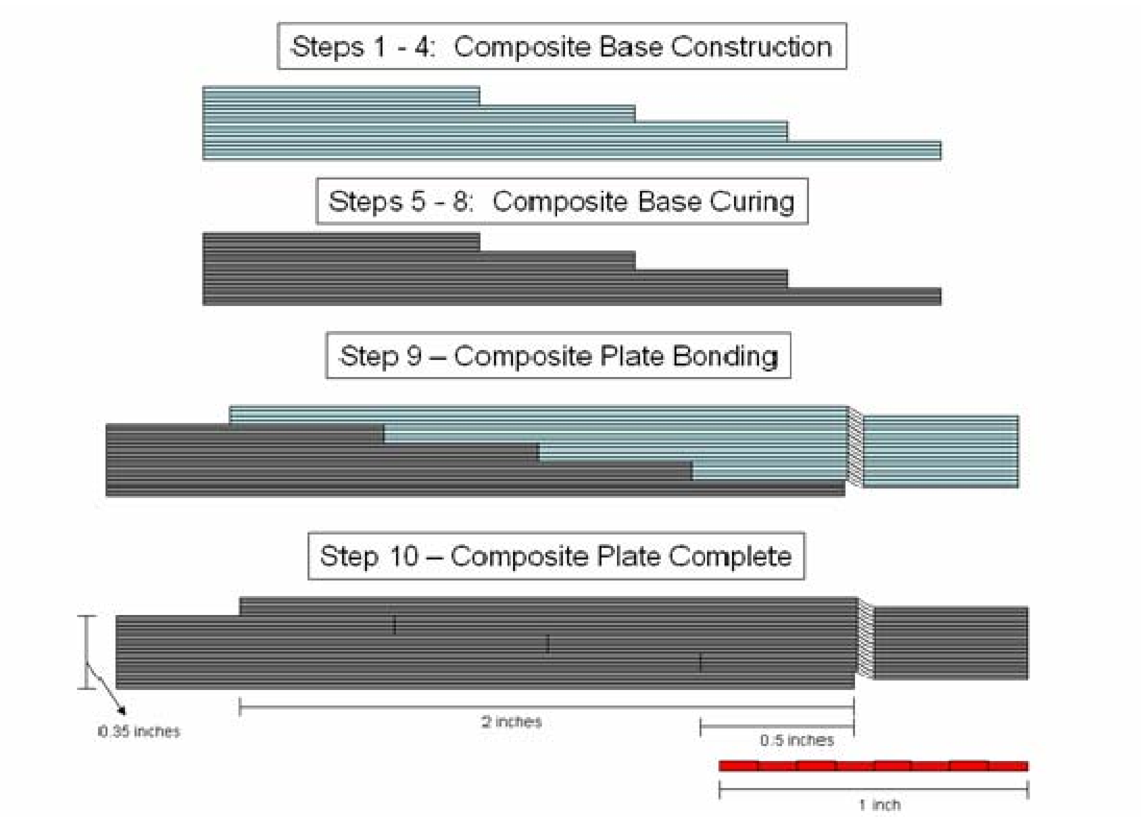


Figure 3. Composite Layup Procedure.

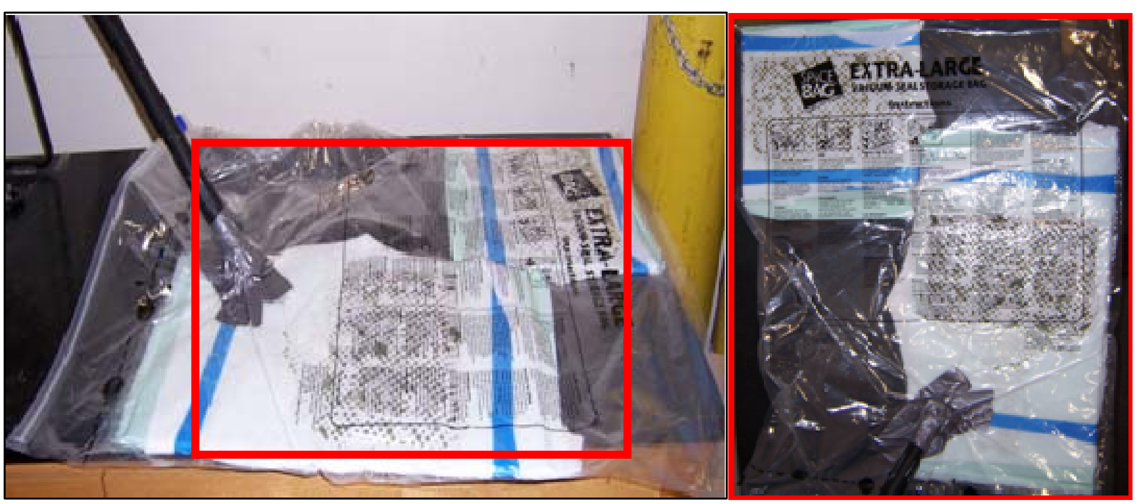


Figure 4. Vacuum Bag Setup

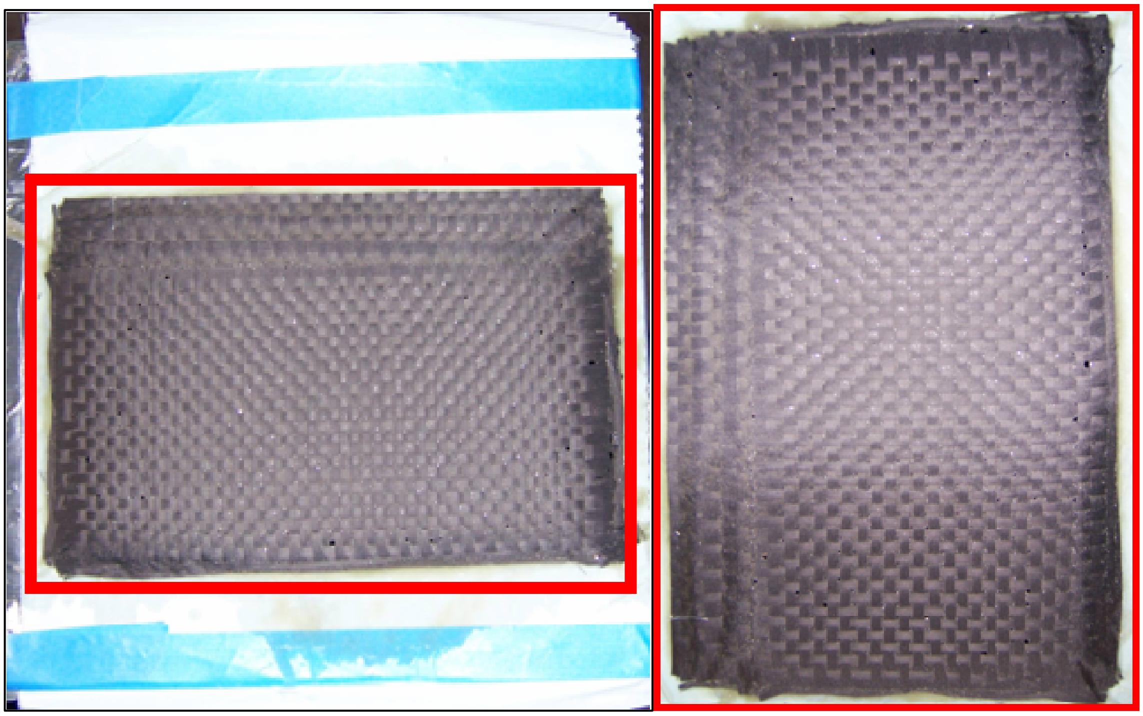


Figure 5. Sheet Base Construction

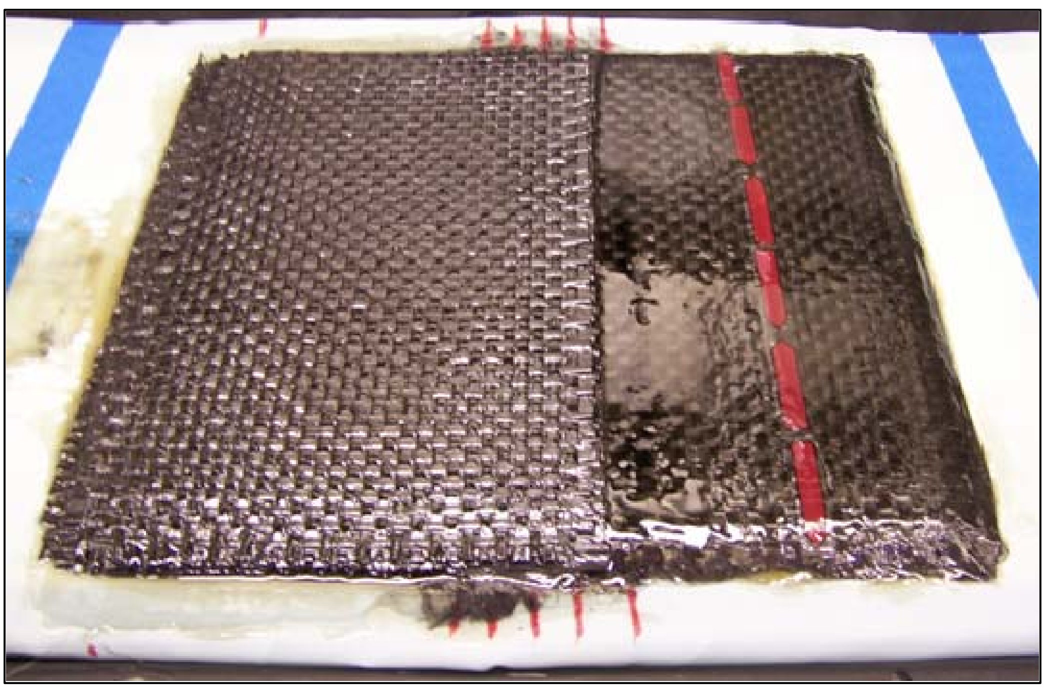


Figure 6. Complete Sheet (Prior to Vacuum Curing)

Figure 7. Complete Sheet (Following Vacuum Curing)

B. CARBON NANOTUBE INTEGRATION

Carbon Nanotubes (CNT) were applied along the joint interface because the majority of non-buckling failures under a tensile or compressive load occur at that location [13]. The nanotube application was designed to reinforce the inherent weak spot in joint construction.

The benefits of carbon nanotube reinforced polymers have been documented on several occasions. For example, an epoxy based polymer matrix composite recorded a 20% increase in modulus strength in both tension and compression [14].

1. Basic Structural Characteristics

The carbon nanotube itself has a molecular structure similar to rolled graphite. The hexagonal array means that each carbon atom will have 3 nearest neighbors [15]. If the

nanotube consists of only one layer it is a Single Walled Carbon Nanotube (SWCNT). The addition of layers around the CNT creates Multi-Walled Carbon Nanotubes (MWCNT).

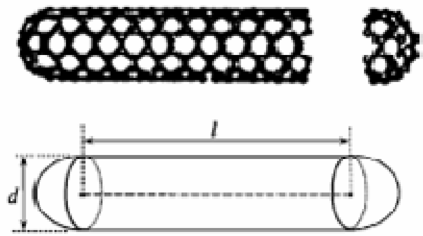


Figure 8. Nanotube Structure (From Ref. [16])

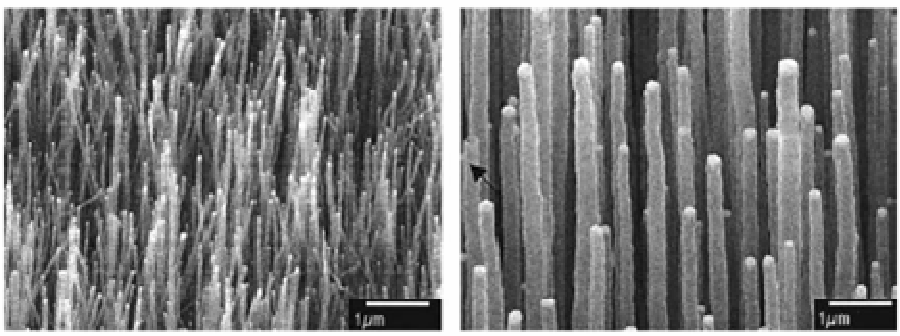


Figure 9. Micrograph of Multi-Walled CNTs (Diameter = 40-50nm & 200-300nm)(From Ref. [17])

The resulting strength from this molecular arrangement reveals an exceptionally high elastic modulus. Theoretical and experimental conclusions suggest that the elastic modulus of the CNT is greater than 1 TPa [18].

Despite the outstanding strength characteristics of the nanotube, structural benefits when used to reinforce a polymer matrix composite are not guaranteed. Other mitigating circumstances help determine whether CNT reinforcement is beneficial. Specifically interfacial bonding strength between the polymer matrix and CNT is crucial. This characteristic along with CNT wettability, and CNT fiber orientation can influence the properties of

the composite [19]. Wettability is particularly important with regard to polymer matrices because the liquid matrix must bond to the fiber through direct contact. Thermosets, such as vinyl ester, show greater wetting characteristics relative to thermoplastics. Greater wettability yields better composites and potentially indicates that thermosets are more inclined to carbon nanotube reinforcement [20].

2. Dispersion and Application Procedures

Referring to the steps outlined in the Test Joint Construction Procedures the CNTs were introduced to the system following Step 8. The following steps are an amendment to the previously mentioned procedure, for the application of CNTs.

Step 8A: After eight hours of curing, turn off the vacuum, remove aluminum plate from the bag, and remove the top plies. Half of the test joint plate has been constructed.

Step 8B: Spread the dispersed nanotubes in solution across the step interface of the composite plate base.

Step 8C: Allow dispersing agent to evaporate leaving only the CNTs at the joint interface.

Step 9: Repeat Step 1 through Step 7 along the step interface of the completed half. Ensure the top 4 sheets of carbon fiber create an overlap at least 1.3cm in length.

Step 10: After eight hours of curing, remove all plies from the top and bottom of the composite joint plate. The composite plate is now ready for sample preparation.

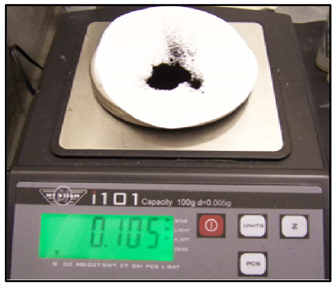


Figure 10. Carbon Nanotube (Prior to application)

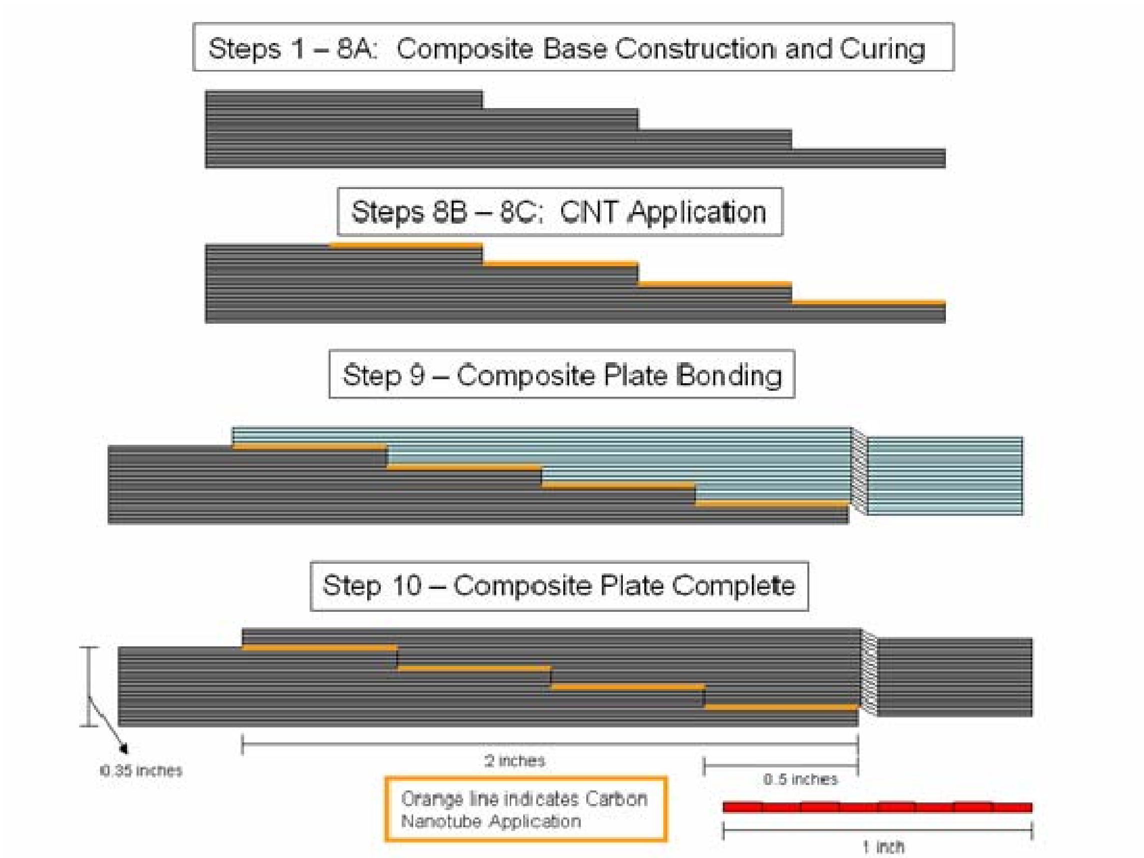


Figure 11. Nanotube Application Region

a. *Phase 1: Dispersion Agent*

Although control of CNT orientation was not possible for this experiment, an effort was made to increase CNT wettability which in turn could potentially increase the interface bonding strength between the CNT and

the matrix. The CNTs were initially dispersed separately in both ethylene glycol and acetone to determine which one was a better dispersing agent.

The CNTs show better dispersion characteristics in the ethylene glycol. However, the ethylene glycol leaves a slight residue after being allowed to evaporate for 24 hours. The CNTs did not disperse quite as well in the acetone. However, the acetone did evaporate, residue free, in less than 10 minutes. Acetone also possesses another property that must be considered. Acetone has the potential to chemisorb on nanotubes. CNTs that possess defects are more susceptible to the chemisorption and thereby could potentially change the surface character and consequently the strength characteristics of the defective CNTs. During the dispersing agent comparison, 0.15 grams of MWCNT (Diameter = 20-40nm, Length = 10-30nm, Purity > 95%) were dispersed across an area of 5.08cm x 25.4cm for a surface area concentration of approximately 11.5 grams per square meter.

b. Phase 2: Surface Area Concentration

Following the resolution of the better dispersing agent, surface area concentration was varied to determine the effect of different application amounts to the 5.08cm x 25.4cm joint interface. Two different concentration levels were tested. The type of nanotube that was used was a high quality, 95% pure MWCNT, with a length of 1-5 microns, and a diameter of 15 +/-5nm. The amounts of MWCNT that were used in this phase of experimentation were 0.15g and 0.10g which provided concentration levels of approximately 11.5g/m^2 and 7.5g/m^2, respectively. A set of samples without

nanotube reinforcement were also constructed in order to provide a basis for comparison.

c. Phase 3: Type and Size

After determining the ideal dispersing agent and concentration level, the final phase of experimentation varied several CNT characteristics, in order to attempt to discern the effect those characteristics had on interface strength. Carbon nanotubes of different types and sizes were tested in this phase.

Nanolab Inc. utilized nanoscale science and engineering to create high value products based on Chemical Vapor Deposition [21]. Single-walled, conventional multi-walled, and bamboo structured multi-walled carbon nanotubes of various lengths and diameters were tested. Bamboo structured nanotubes are discontinuous along the length and have many edge sites for functionalization. Functionalization is the process of physically or chemically attaching in molecules (functional groups), to the wall of an imperfect carbon nanotube without significantly changing the nanotubes' desirable properties. This makes CNTs more easily dispersible in liquids [22].

In addition to the high quality nanotubes tested in this phase, there was an additional set of samples constructed with more economical nanotubes. The idea behind the economy-based test samples was cost reduction. The expense of carbon nanotubes creates a question of feasibility when applied to large scale construction applications. The economic option tested was similar in size, shape, and purity but cost 90% less per gram [23]. The economic option may provide the Navy with a more affordable alternative ideally without sacrificing the

reinforcement benefits relative to the other carbon nanotubes tested. The following table provides a list of the CNTs that were tested.

Multiwall carbon nanotubes, outer diameter 30 +/-15nm, Length 1-5 microns, Purity > 95%
Multiwall carbon nanotubes, outer diameter 15 +/-5nm, Length 1-5 microns, Purity > 95%
Multiwall carbon nanotubes, outer diameter 15 +/-5nm, Length 5-20 microns, Purity > 95%
Multiwall carbon nanotubes, outer diameter 30 +/-15nm, Length 5-20 microns, Purity > 95%
Multiwall carbon nanotubes, outer diameter 25 +/-5nm, Length 10-30 microns, Purity > 95% (Economic)
Bamboo structure multiwall carbon nanotubes, outer diameter 30 +/-15nm, Length 1-5 microns, Purity > 95%
Bamboo structure multiwall carbon nanotubes, outer diameter 30 +/-15nm, Length 5-20 microns, Purity > 95%
Single wall carbon nanotubes, outer diameter 1-1.5nm, length 1-10 microns, Purity > 80%

Table 1. Nanotube Structure

The three phases of testing, previously described, were designed to determine the optimum combination of dispersing agent, surface area concentration, and CNT type for composite joint reinforcement. The goal of this research, ideally, is to prove the positive effect of carbon nanotube joint reinforcement.

III. EXPERIMENTAL SETUP AND TESTING

A. SAMPLE PREPERATION

The composite test joints were manufactured in accordance with the steps outlined in the previous section of this report. Due to the coarse nature of the carbon fiber weave used throughout this research, the joints had to be constructed in sheets. The sheets were cut into test joints by using a 1.52m x 2.44m Jet Edge Waterjet cutter. This tool was able to produce test joints with identical length and width. The accuracy of the water jet cutter eliminated the need for additional machining to achieve the desired specimen size. Each specimen was 24.0 to 24.2 cm in length and 3.8 to 3.9 cm in width. Since the layup procedure for constructing the sheets was standardized the thickness for each specimen was always between 0.8 and 0.9 cm. This provided a sample transverse cross sectional area of 3.0 to 3.5 cm^2.

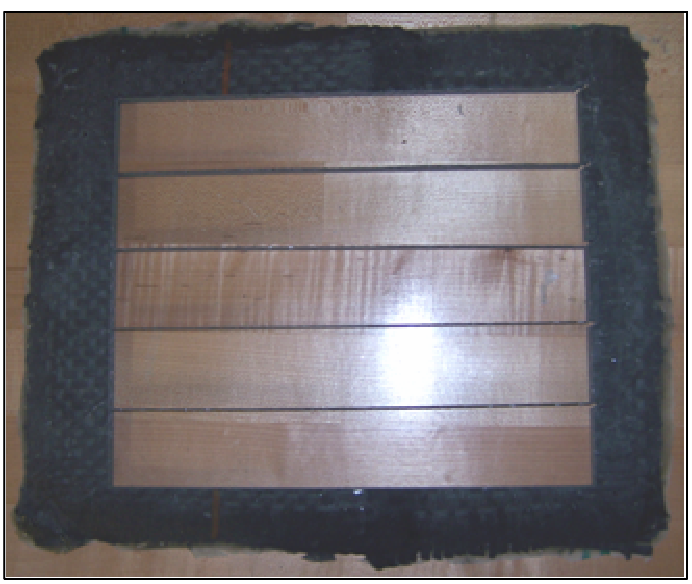


Figure 12. Composite Sheet (Following water jet cutting)

Figure 13. Completed Test Joint

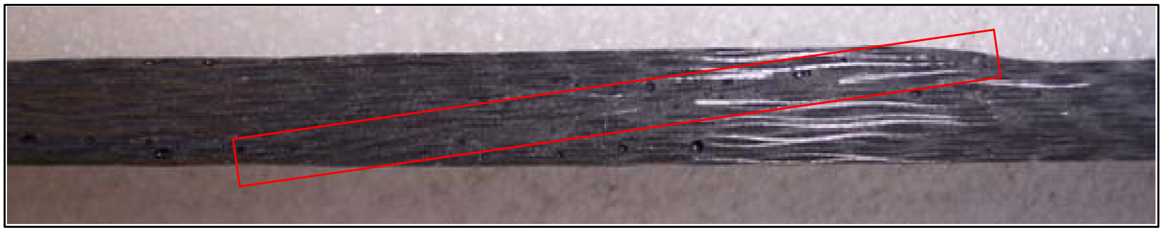


Figure 14. Scarf Joint Interface

B. SAMPLE COMPRESSION TESTING

Each sample was set up the same for testing. They were mounted longitudinally in the Instron Tension/Compression Machine (Model Number: 4507/4500) with a 100kN load cell. The samples were clamped approximately 6 cm from each end. This provided an effective test joint length of 12.0 to 12.1 cm between the top and bottom clamps. Since the samples were to be loaded in compression aluminum blocks were wedged between surface of the clamp and the end of the sample. These wedges prevented the samples from splintering at the ends which ensured that the failure of the test joint would occur along the joint interface.

Figure 15. Sample Testing

Once the sample was set up correctly, the computer program Series IX was enabled to control the load and record the data. The recorded data included applied compressive load and displacement. The program required manual input of each samples length, width, and thickness to ensure the proper stress versus strain relationships were calculated.

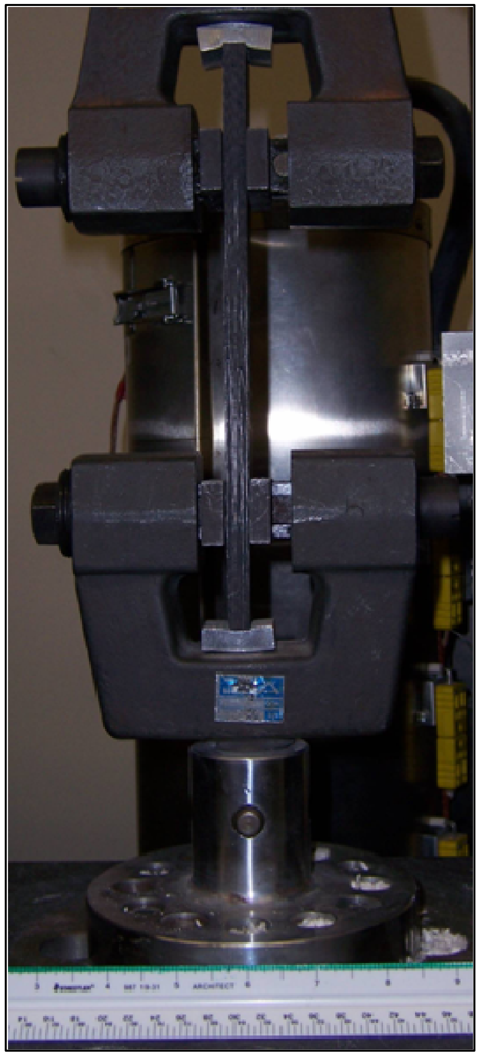


Figure 16. Mounted Test Sample

While the stress versus strain relationships was being tabulated, the crack initiation and propagation were observed using high speed video equipment. The high speed camera was set at 1500 frames per second with additional light fixtures rigged to illuminate the sample. The purpose of this aspect of experimentation is to discern whether or not there is a difference in crack initiation and propagation between non-reinforced and CNT reinforced joint interface.

IV. RESULTS AND DISCUSSION

A. PHASE 1

Phase 1 experimentation consisted of two sets of carbon nanotube reinforced test samples. The CNTs were dispersed separately in both ethylene glycol and acetone to determine which one was the better dispersing agent. There was another set of test joints constructed without reinforcement in order to provide a basis for comparison between samples with and without carbon nanotube reinforcement. The best three of five trials were used for each case and the results have been in Appendix A.

1. Results

Each test sample fractured at the expected location along the diagonal step interface of the joint. An example of the failure is shown below.

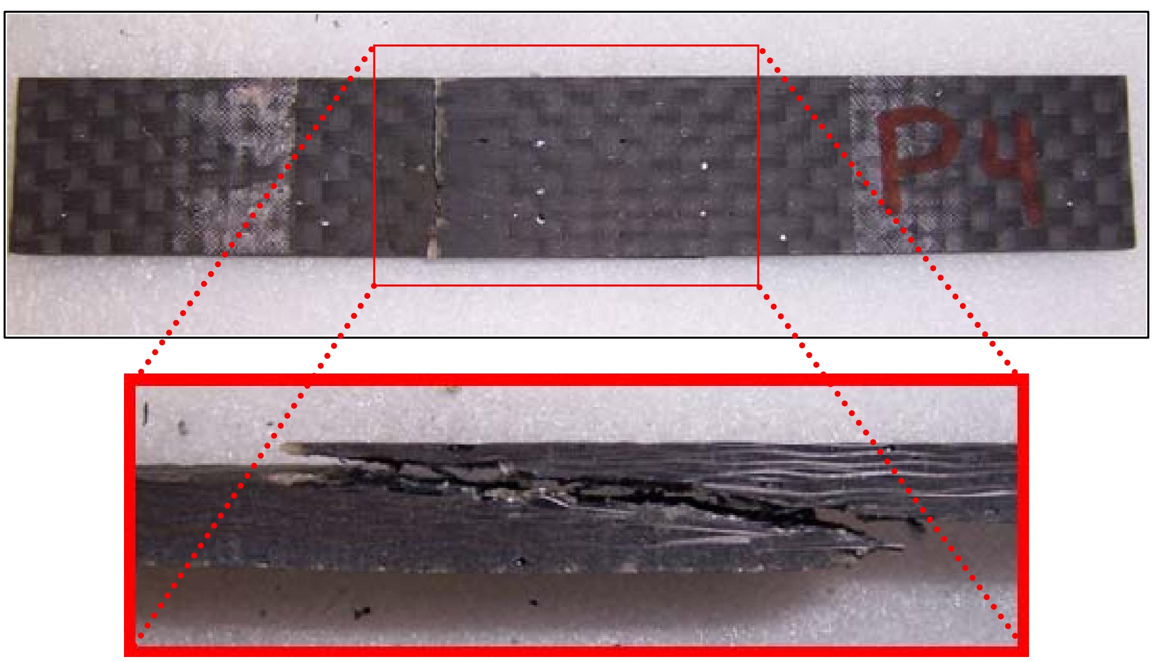


Figure 17. Test Joint Failure Location

The average results of the three most consistent tests are shown as follows:

	Average Max Load (KN)
Plain	45.31
Acetone	48.52
Glycol	30.93
	Average Max Stress (Mpa)
Plain	131.36
Acetone	141.84
Glycol	87.59
	Average Modulus (Mpa)
Plain	49.71
Acetone	54.52
Glycol	37.86

Minimum of 3 tests.

CNT Characteristics	
Diameter	20-40nm
Length	10-30nm
Puruty	>95wt%

Table 2. Phase 1 Results

Figure 12 shows the average maximum stress for all three sets of test joints including the standard deviation for each set of sample data.

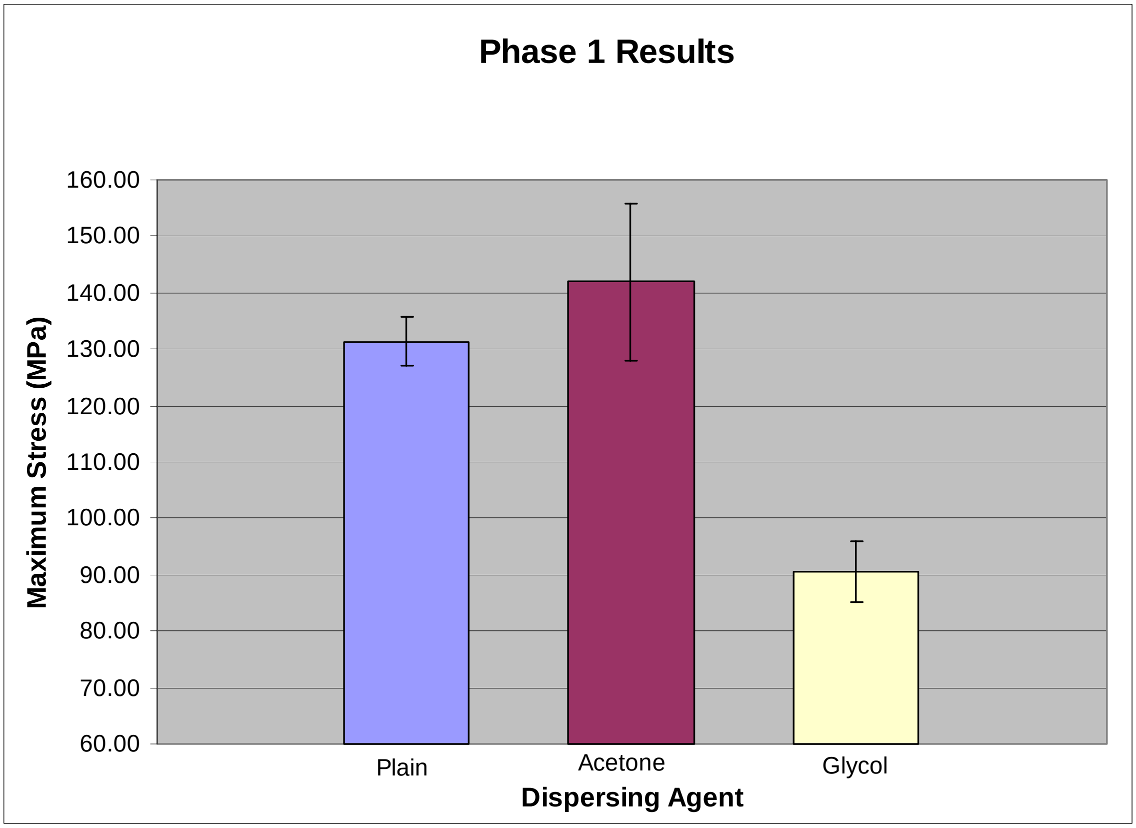


Figure 18. Maximum Stress (Phase 1)

2. Discussion

The object of phase 1 of this research was to determine which chemical was a better dispersing agent, ethylene glycol or acetone. Based on the results, one can conclude that the acetone is the better choice for a dispersing agent. The acetone exhibited more than a 50% greater capacity for load and stress. Based on the slope of the stress versus strain curves the modulus of elasticity for the acetone-nanotube solution was more than 45% greater than the ethylene glycol-nanotube solution.

There were also encouraging results when comparing the data from the acetone-nanotube solution to the data from the plain test set there was an observed 5% to 10% increase

in maximum load, maximum stress, and elastic modulus. Despite these encouraging numbers, the data does not conclusively determine an enhancement of joint interface strength because of the closeness of the two data sets, the large standard deviation, and the small number of test samples. The final determination of strength enhancement will be examined in Phase 3.

B. PHASE 2

Phase 2 experimentation consisted of two sets of carbon nanotube reinforced test samples with different surface area concentrations. The CNTs were dispersed using acetone as the dispersing agent based on the results from phase 1. The concentration levels tested were 7.5 g/m^2 and 11.5 g/ m^2. Based on the size of the composite sheets that were constructed and the 4:1 aspect ratio along the joint interface, the amount of carbon nanotubes used per sheet were 0.10g and 0.15 g respectively. There was another set of test joints constructed without reinforcement in order to provide a basis for comparison between samples with and without carbon nanotube reinforcement. The best four of five trials were used for each case and the results have been included in Appendix B.

1. Results

Almost every test sample fractured at the expected location along the diagonal step interface of the joint. During testing there was a trend in crack initiation and propagation that was observed. For the majority of test joints, the crack initiated at either the base of the bottom step or in the center of the joint and propagated diagonally along the joint interface. An example of each failure is shown in Figure 19 and Figure 20. Fracture

initiation and propagation was explored further in Phase Three using high speed video equipment.

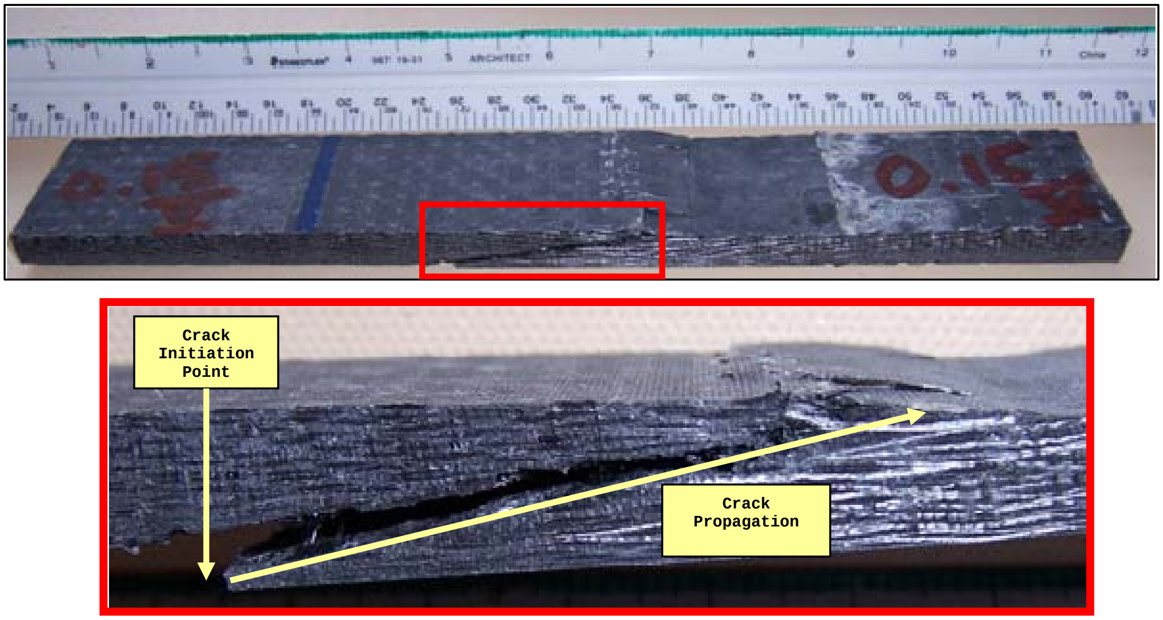


Figure 19. Crack Initiation and Propagation (Base)

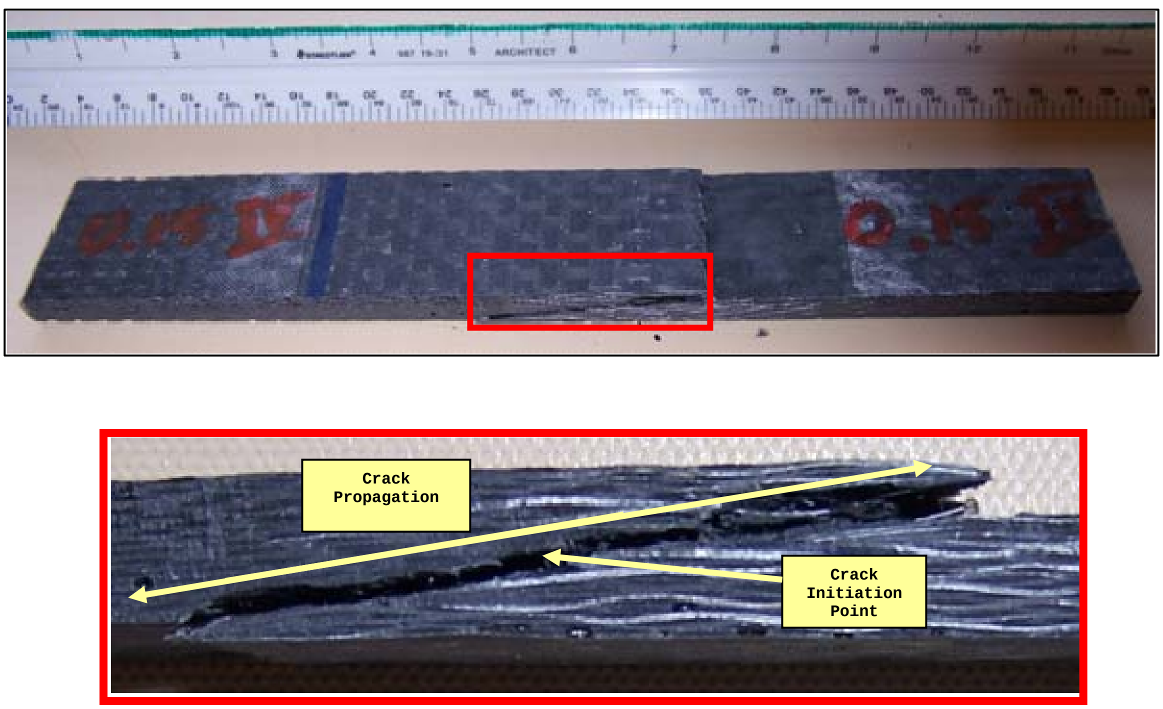


Figure 20. Crack Initiation and Propagation (Middle)

The average results of the four most consistent tests are shown in Table 3:

PHASE 2 SUMMARY	
	Average Max Load (KN)
0.00g/m^2	54.99
7.5g/m^2	55.19
11.5g/m^2	50.21
	Average Max Stress (Mpa)
0.00g/m^2	159.52
7.5g/m^2	176.47
11.5g/m^2	168.34

Minimum of 4 tests.	
CNT Characteristics	
Diameter	10-20nm
Length	1-5 microns
Purity	>95wt%

Table 3. Phase 2 Results

The average maximum stress for each group of test samples is shown in Figure 20. The figure shows the standard deviation of the data as well, in order to gain a greater understanding of the trends and data consistency that is prevalent in the results.

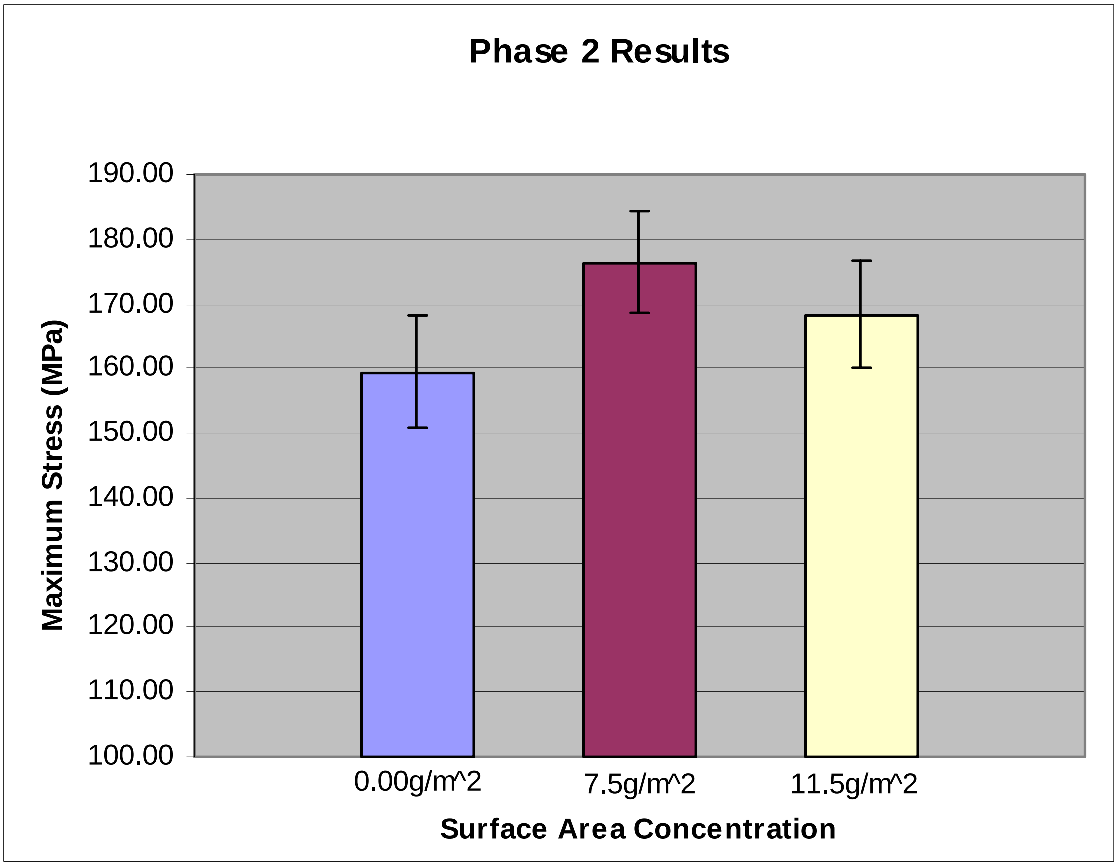


Figure 21. Maximum Stress (Phase 2)

2. Discussion

The purpose of phase two was to examine the effect different CNT surface area concentrations had on composite joint interface strength. It was evident from Figure 14 that the surface area concentration of carbon nanotubes did affect the strength of the composite joint. Both the 7.5g/m^2 and the 11.5g/m^2 concentration levels resulted in a strength increase over the non-reinforced composite joints. The greatest increase occurred with the 7.5g/m^2 concentration level which revealed an improvement in joint strength of 10.63 percent. This percentage was almost double the strength improvement witnessed by the 11.5g/m^2 concentration level.

Even more importantly the inclusion of the standard deviation shows no overlap between the results of the non-reinforced and the results of the 7.5g/m^2 concentration level. This proves not only that the 7.5g/m^2 concentration level is superior to 11.5g/m^2, but also that the carbon nanotube reinforcement has a definite positive impact on composite scarf joint strength. As shown in Table 3, even the lowest observed maximum stress in the 7.5g/m^2 data set is greater than every observed value of maximum stress of the non-reinforced data set.

C. PHASE 3

Phase 3 experimentation consisted of eight sets of test samples. One set of samples was constructed without CNT reinforcement to provide a basis for comparison. A second set of test joint was constructed with single-walled carbon nanotubes. The remaining six sets of test joints were constructed with different types of multi-walled carbon nanotubes. Table 4 lists the various types of MWCNTs used along with their designation letter.

A =	Multiwall carbon nanotubes, outer diameter 30 +/-15nm, Length 1-5 microns, Purity > 95%
B =	Multiwall carbon nanotubes, outer diameter 25 +/-5nm, Length 10-30 microns, Purity > 95%
C =	Multiwall carbon nanotubes, outer diameter 15 +/-5nm, Length 5-20 microns, Purity > 95%
D =	Multiwall carbon nanotubes, outer diameter 30 +/-15nm, Length 5-20 microns, Purity > 95%
E =	Bamboo structure multiwall carbon nanotubes, outer diameter 30 +/-15nm, Length 1-5 microns, Purity > 95%
F =	Bamboo structure multiwall carbon nanotubes, outer diameter 30 +/-15nm, Length 5-20 microns, Purity > 95%

Table 4. Types of Multi-Walled Carbon Nanotubes

MWCNT groups A, C, D, E, and F along with the SWCNT were all ordered through the same vendor. The nanotubes

used in Group B were ordered through a separate vendor at one fourth the cost for CNTs of similar size and purity. MWCNT B was an economic alternative to the other MWCNT.

The CNTs were applied using acetone as the dispersing agent based on the results from phase 1. The surface area concentration level used for each set of reinforced test samples was 7.5 g/m^2 based on the results from Phase 2. Based on the size of the composite sheets that were constructed and the 4:1 aspect ratio along the joint interface, the amount of CNT used for reinforcement was 0.10 grams per sheet. Five specimens were tested for each type of CNT, and the results of each test were used with the exception of trial E-4, which yielded poor data due to improper setup. The results are shown in Tables 5 and 6, and the data has been included in Appendix C.

1. Results

The average results of all recorded tests are shown in Tables 5 and 6.

PHASE 3 SUMMARY	
	Average Max Load (KN)
NO CNT	44.92
SWCNT	44.20
MWCNT-A	44.06
MWCNT-B	44.61
MWCNT-C	49.10
MWCNT-D	48.66
MWCNT-E	48.66
MWCNT-F	50.96

Table 5. Phase 3 - Average Maximum Load

	Average Max Stress (Mpa)
NO CNT	140.35
SWCNT	145.21
MWCNT-A	145.34
MWCNT-B	145.49
MWCNT-C	135.28
MWCNT-D	156.08
MWCNT-E	156.86
MWCNT-F	156.69

Table 6. Phase 3 - Average Maximum Stress

Figure 23 shows the average maximum stress for each case. Each case is plotted in conjunction with their respective standard deviation to show the consistency of the data sets.

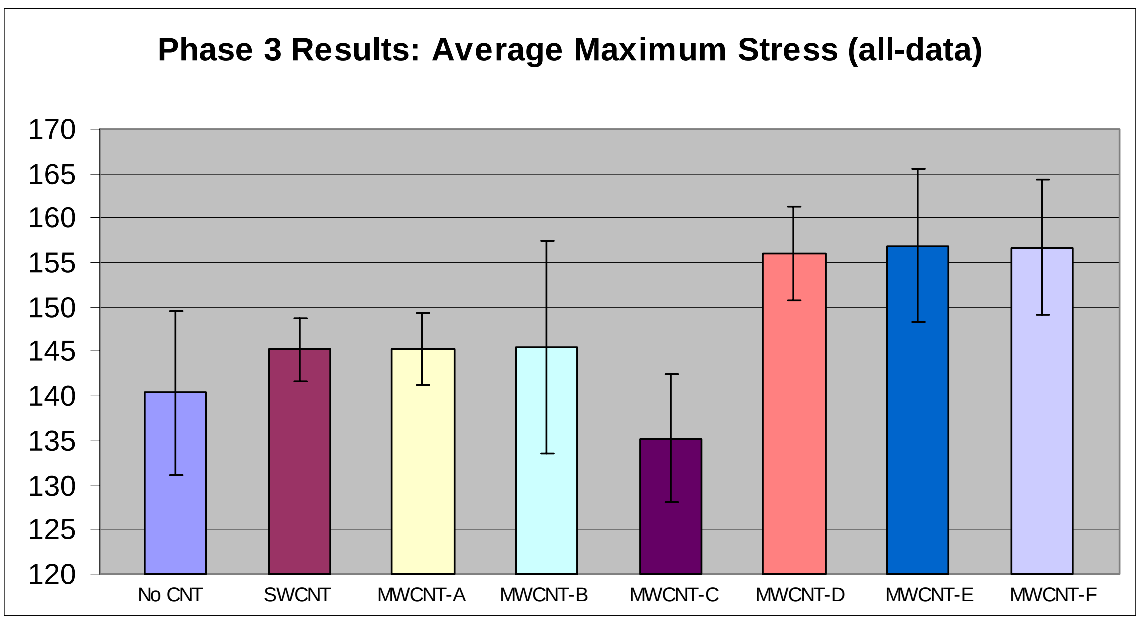


Figure 22. Phase 3 Results

Table 6 and Figure 24 depict the elastic modulus for each data set. Due to the slipping of the grips and the deformation of the aluminum block buffers, it was not

possible to obtain an accurate stress versus strain relationship at the higher forces. In order to obtain the elastic modulus for each case, the 3 most consistent stress versus strain relationships between strain values of 0.5 and 1.0 were averaged and plotted. The elastic modulus was then determined by calculating the slope of the stress versus strain curve between strain values of 0.5 and 1.0.

	Average Elastic Modulus
NO CNT	64.58
SWCNT	73.56
MWCNT-A	81.49
MWCNT-B	75.38
MWCNT-C	70.87
MWCNT-D	74.41
MWCNT-E	74.41
MWCNT-F	69.21

Table 7. Phase 3 – Average Elastic Modulus

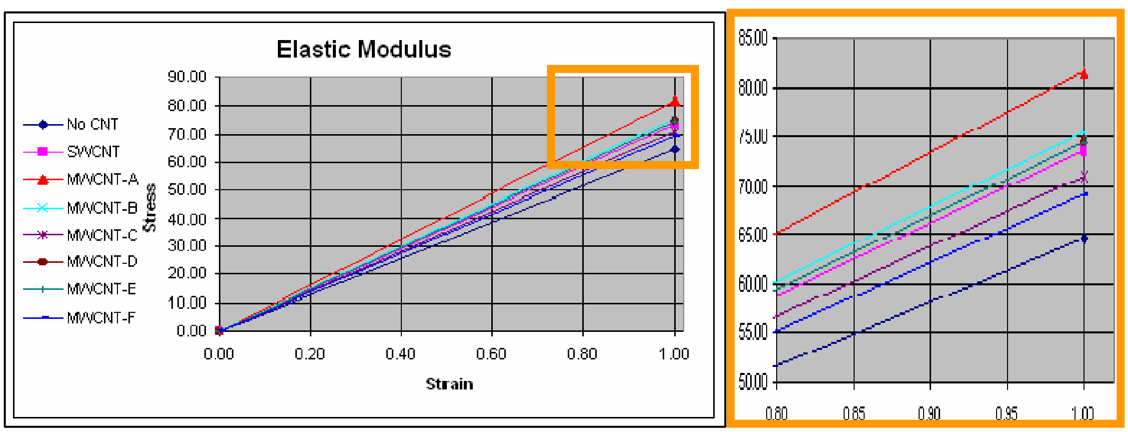


Figure 23. Phase 3 - Elastic Modulus Comparison

2. Discussion

Phase 3 observed maximum stress values lower than the stress values observed in Phase 2 in every case including the non-reinforced, which was constructed in both phases. The potential cause for the difference could be the shelf

life of the resin. Phase 2 was constructed when the resin was four months old, while Phase 3 was constructed when the resin was five to five and a half months old. The strength properties of the resin begin to degrade after approximately four months [24]. The non-reinforced specimens were constructed first in Phase 3 in order to ensure that the results were not biased towards the reinforced specimens due to the aging resin. Groups F and A were the last two sets of test joints constructed.

Each group provided a joint strength increase, compared to the non-reinforced specimens, with the exception of group C. The greatest strength increase was observed by Groups D, E, and F. All three of those groups demonstrated an average strength increase of greater than 11 percent. Of these three groups, it appears as though Group D possesses the best strength enhancement characteristics. It had greater than an 11 percent increase in strength and possessed the most consistent data of the three top reinforcements. This consistency can be seen by observing the standard deviations shown in Figure 23. Table 8 shows a summary of the strength enhancements provided by the carbon nanotube reinforcement.

	% Strength Increase
NO CNT	0.00
SWCNT	3.46
MWCNT-A	3.56
MWCNT-B	3.67
MWCNT-C	-3.61
MWCNT-D	11.21
MWCNT-E	11.76
MWCNT-F	11.64

Table 8. Phase 3 – Percent Strength Increase

Groups E and F are Bamboo CNTs. They have regularly occurring compartment-like graphitic structures inside the nanotube similar to the bamboo plant [25]. These types of CNTs were used with the notion that the compartment-like graphitic structures could provide additional support when used for reinforcement and the open ended molecular structure of the multi-walled bamboo CNT would increase wettability and functionalization. This would allow for increased interfacial bonding which would in turn increase the load transfer between the resin and the CNT which would ultimately improve the joint interface strength of the composite structure. The strength increase indicated in Table 8 confirms that the bamboo structure has better strength characteristics compared to conventional CNTs of similar size and purity.

Group B, the economic option, had some samples that provided strong reinforcement and others that were actually weaker than the non-reinforced specimens. As a result the average strength was greater than the non-reinforced samples, but the standard deviation was quite large. The standard deviation of group B was almost 30 percent larger than any other group. All MWCNT groups were 95% pure, but perhaps the economic option encountered a higher frequency of defects.

The modulus of elasticity increased dramatically in every case. The greatest increase came with Group A which displayed over a 26 percent increase in modulus compared to the test joints without CNT reinforcement. Of the three groups that had the greatest strength increase, D, E, and F, groups D and E each had modulus increases greater than 15 percent. Group F had the lowest impact of all the groups

with and increase in modulus of just over 7 percent. Table 9 provides a summary of the Elastic Modulus increase observed in Phase 3.

	% Modulus Increase
NO CNT	0.00
SWCNT	13.91
MWCNT-A	26.19
MWCNT-B	16.73
MWCNT-C	9.75
MWCNT-D	15.23
MWCNT-E	15.23
MWCNT-F	7.18

Table 9. Phase 3 – Percent Elastic Modulus Increase

The majority of test sample fractured at the expected location along the diagonal step interface of the joint. The trends in crack initiation and propagation observed in Phase 2 were verified in Phase 3 using a high speed camera. The majority of test joints initiated cracks at either the base of the bottom step or in the center of the joint and propagated diagonally along the joint interface. Examples of each have been included with excerpts from the high speed video to support illustrate.

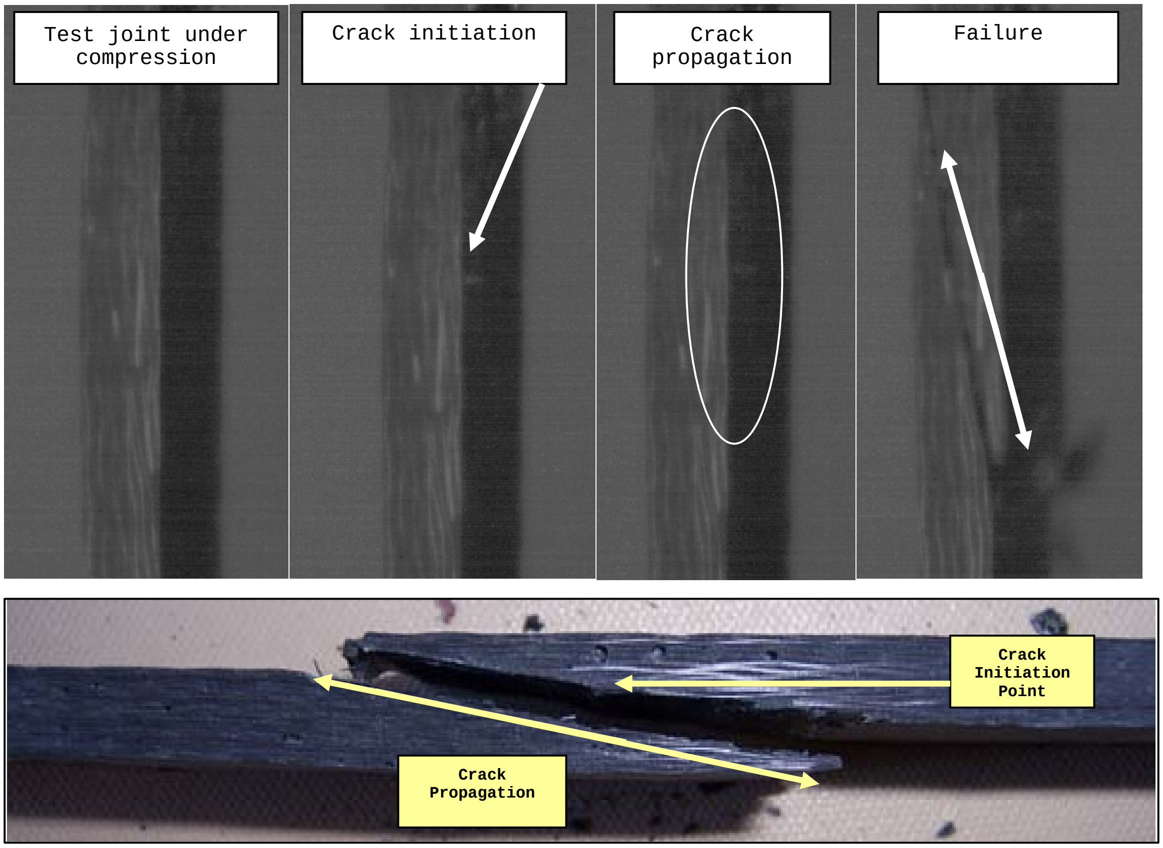
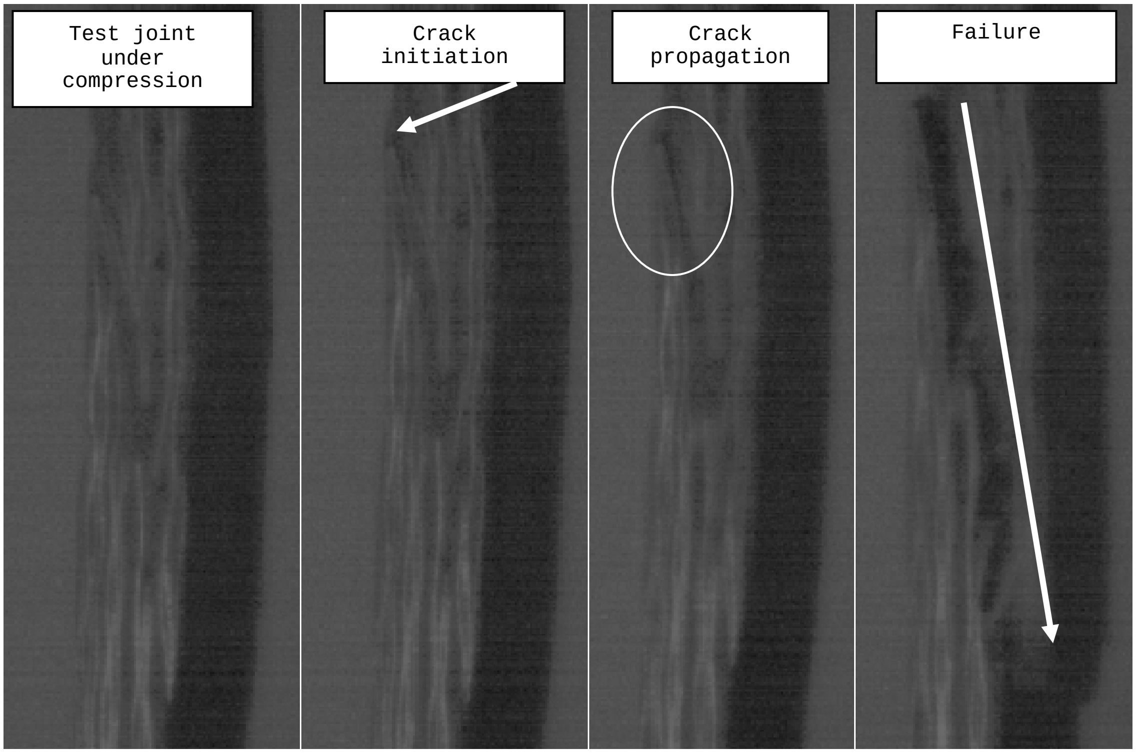


Figure 24. Crack Initiation and Propagation (Middle)

There were several trials which were unobserved by the high speed camera due to the speed of failure. Of the fractures that were observed, failure location at the center of the joint occurred two times more often than any other mode of failure. There were also several examples of delamination at the joint base. Figure 22 shows the progression from crack initiation to fracture for this type of failure.



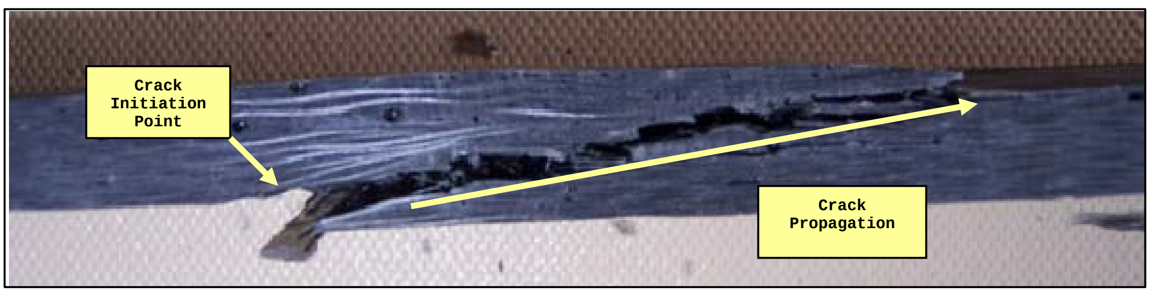


Figure 25. Crack Initiation and Propagation (Base)

There was one other type of fracture that rarely occurred, where the crack propagation did not follow the path of the joint interface. The crack initiated at the base but instead of propagating along the interface, it seemed to propagate at a 45 degree angle away from the interface. The test joints are constructed as shown in Figure 24.

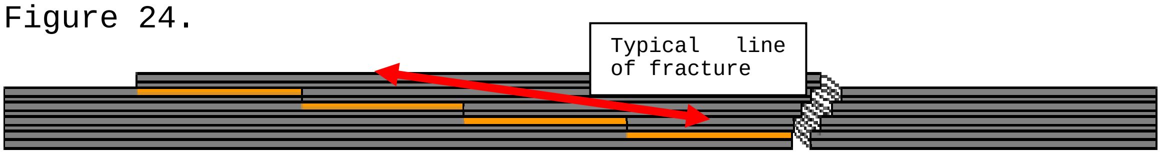


Figure 26. Typical line of fracture

Figure 27 shows an alternate line of fracture compared to Figure 26. When the test joint does not fail in the middle of the interface, the crack initiation point is at the base of the interface. Usually this type of fracture will follow the joint. However, in this case the fracture seemed to follow the path of the step down caused by the overlap that is inherent in Method 1 composite construction.

Figure 27. Alternative line of fracture

Figure 28 shows a test specimen that failed along the alternative fracture line. The figure has been enlarged to match the schematic shown in Figure 27.

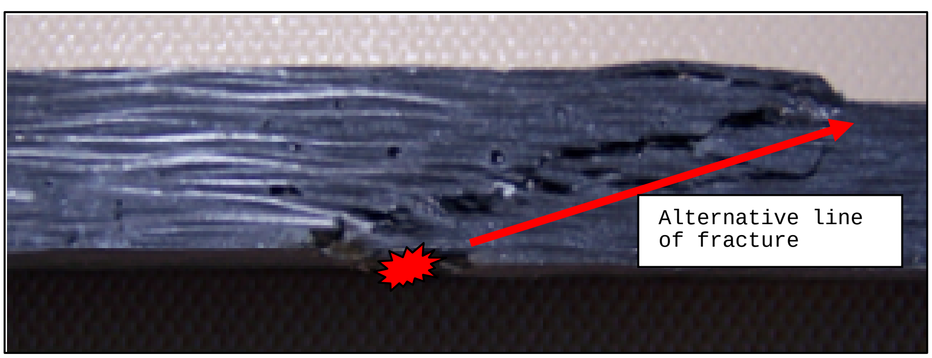


Figure 28. Test example of alternative line of fracture

This alternative fracture phenomenon did not happen consistently until Phase 3. In phase 3 only one group had the majority of these types of fractures. Group D had every test joint fail along the alternative line of fracture.

This group also happened to have the most consistent strength enhancement and the highest elastic modulus of the three top CNT reinforcements. Figure 29 shows all five test joints in this group with the same line of fracture.

Figure 29. Group D Fracture

A potential explanation for the consistency of this failure in Group D is that the CNTs used provided enough of an enhancement in strength and stiffness along the joint interface that the interface ceased to be the weakest portion of the specimen. Instead the samples failed along second weakest portion of the joint, the step down created by the overlap associated with Method 1 composite

construction. The mode of this type of failure was localized fiber buckling. Normally this type of failure is intermittent. The consistency in Group D suggest the joint was reinforced enough to make it stronger than the stress required to cause the localized buckling failure at the location of the fabric down step.

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V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This research investigated many aspects of carbon nanotube reinforcement of the vinyl ester resin, Derakane 510A. Phase 1 concludes that acetone is a better dispersing agent compared to ethylene glycol. The acetone dispersion proved to be greater than 50 percent stronger than the ethylene glycol dispersion. This is due in part to the acetone evaporating residue free compared to the ethylene glycol.

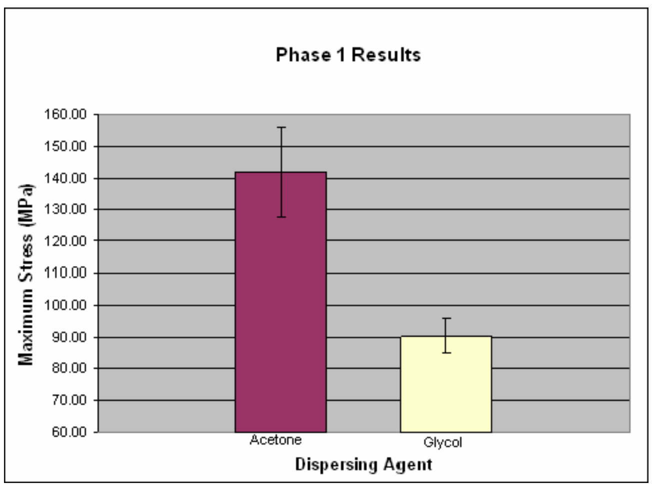


Figure 30. Phase 1 Conclusion

Phase 2 investigated the effect of carbon nanotube surface area concentration. This phase proves that the reinforcement benefits provided by localized application of carbon nanotubes, is dependent upon surface area concentration. The dependency on surface area concentration was proven by testing samples with concentration levels of $7.5 g/m^2$ and $11.5 g/m^2$. A comparison reveals that the lesser concentration level of the two produces better

reinforcement characteristics. A 7.5g/m^2 surface area concentration was stronger by approximately 5 percent compared to 11.5g/m^2. The lower concentration level provided better carbon nanotube spacing which increased wettability and in turn increased carbon nanotube interfacial bonding with the vinyl ester resin.

This phase also shows conclusively that localized reinforcement of composite scarf joints with carbon nanotubes works. The reinforced test samples were approximately 10 percent stronger than the non-reinforced and the standard deviations of both data sets remained outside one another. Since only two concentration levels were tested the optimal level is unknown. The conclusions from Phases 1 and 2 allowed for a refined investigation of the optimal type of carbon nanotube to be used for reinforcement.

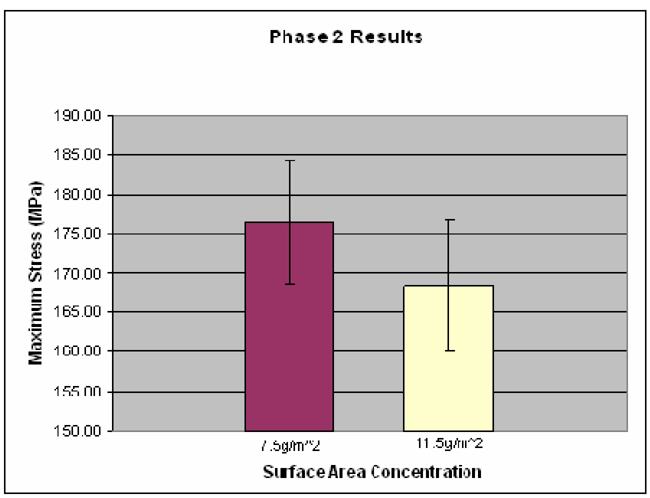
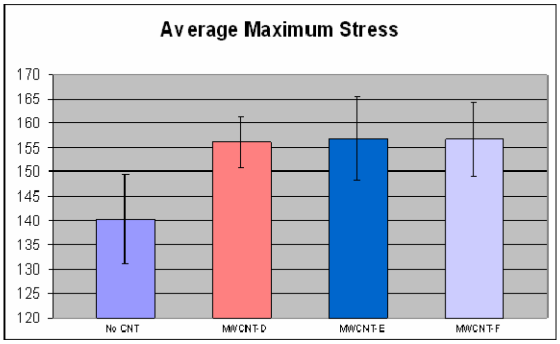


Figure 31. Phase 2 Conclusion

From the data accumulated throughout Phase 3 there are a myriad of conclusions that can be reached. First and foremost, the phase accomplished its purpose to identify

the ideal type of carbon nanotube for localized scarf joint interface reinforcement. There were three breakout sets of samples each providing greater than an 11 percent increase in strength. Two of the breakout sets of test samples were reinforced with bamboo structure multi-walled carbon nanotubes with equal diameters of 30nm +/- 15nm and unequal lengths of 1-5um for one group and 5-20um for the other. The third breakout group was a conventional multi-walled carbon nanotube with the same diameter as the bamboo multi-walled carbon nanotubes, 30nm +/- 15nm, and a length of 5-20um. The shorter bamboo multi-walled carbon nanotube and the conventional carbon nanotube displayed twice the amount of modulus increase over the longer bamboo structure. Between the shorter bamboo structure and the conventional carbon nanotube, the conventional multi-walled carbon nanotube had the most consistent results which translated to a smaller standard deviation.

Since the conventional multi-walled carbon nanotube with a diameter equal to 30nm +/- 15nm and a length of 5-20um achieved one of the highest increases in strength and modulus as well as possessing the most consistent results of all three breakout groups, this type of carbon nanotube is ideal for localized reinforcement of a vinyl ester composite scarf joint. These findings support previous observations of carbon nanotube reinforcement that multi-walled carbon nanotubes are more ideal for polymer reinforcement due to greater surface area [26].



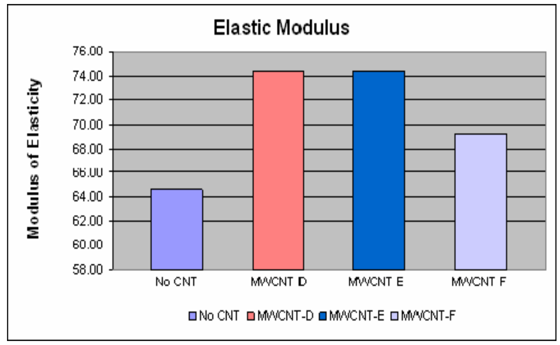


Figure 32. Phase 3 Conclusion

In general the higher diameter carbon nanotubes provide greater strength enhancements compared to single-walled and multi-walled nanotube of lesser diameter. This is most likely due to the greater surface area of the carbon nanotubes with larger diameter. Several interesting observations were apparent when comparing the results of the carbon nanotubes with the same diameter of 30nm +/- 15nm.

When comparing the carbon nanotubes with the same 30nm diameter, the shorter carbon nanotubes provoked a higher increase in elastic modulus. The conventional multi-walled carbon nanotube with a diameter of 30nm +/- 15nm and a length of 1-5um produced the greatest increase is elastic modulus with an average enhancement in stiffness of greater than 26 percent. This observation holds true when both types of 30nm diameter conventional multi-walled carbon nanotubes are compared as well both types of bamboo multi-walled carbon nanotubes.

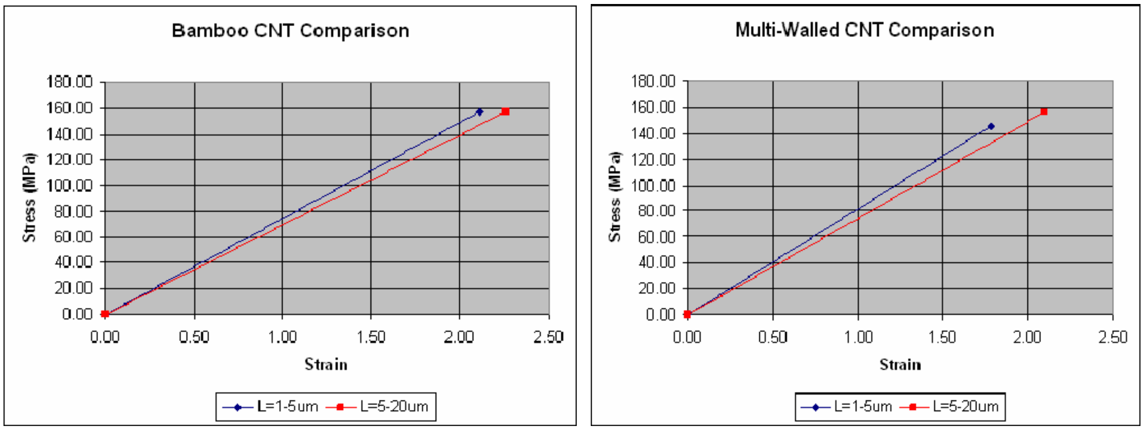


Figure 33. Phase 3 Modulus Comparison - 1

A similar trend was observed while comparing conventional multi-walled carbon nanotubes to bamboo carbon nanotubes. When the conventional and the bamboo multi-walled structures were the exact same size and shape (two cases: 1) Diameter = 30nm +/- 15nm, Length = 1-5um, and 2) Diameter = 30nm +/- 15nm, Length = 5-20um), in both cases the modulus of the conventional multi-walled carbon nanotube was higher.

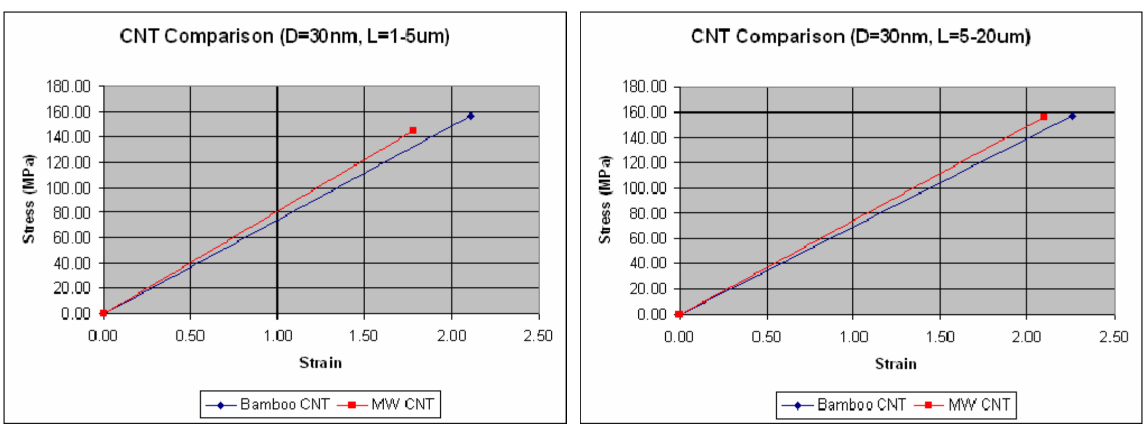


Figure 34. Phase 3 Modulus Comparison – 2

This observation supports the findings delineated in a previous thesis topic researched by J. J. Oh from the Naval Postgraduate School. The study modeled the modulus of a

single-walled carbon nanotube for comparison against a similar model for a bamboo single-walled carbon nanotube. Figure 34 shows a graphical representation of the findings.

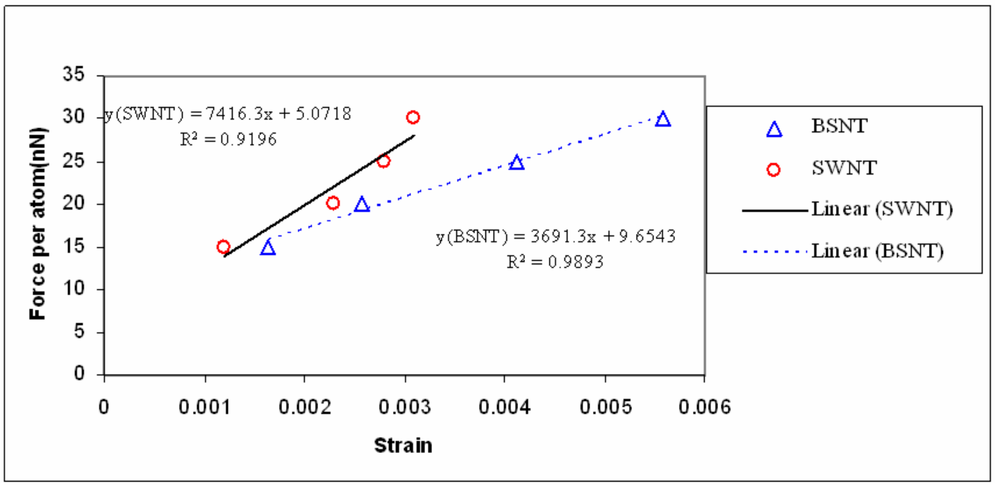


Figure 35. Elastic Linear Regression (From Ref. [27])

Although the comparison modeling was developed for single-walled structures only, the conclusions are similar to the comparison between bamboo and conventional multi-walled carbon nanotubes observed by this research. Oh's work concluded that the modulus of elasticity is greater for conventional single-walled carbon nanotubes compared to their bamboo counterparts. Figure 33 shows the same relationship determined experimentally for multi-walled carbon nanotubes.

With the composite building processes utilized in this research one square meter of composite would weight approximately 5.3 kilograms. Normally carbon nanotube reinforcement would be accomplished through dispersion throughout the resin of the entire panel. Even if only one weight percent of carbon nanotubes were used, the amount required for reinforcement of one square meter would be 53

grams. This study was able to effectively reinforce the weakest area of the composite structure at a fraction of what would have been required for reinforcement throughout. The reinforcement techniques demonstrated in this study would require a mere 1.29 grams of carbon nanotubes to reinforce one square meter of a composite scarf joint. This translates to a cost savings of over 97.5 percent compared to reinforcement through carbon nanotube dispersion within the matrix. Localized reinforcement of the joint interface proved to be a cost effective procedure that enhances composite scarf joint strength and stiffness.

B. RECOMMENDATIONS

Given the success of the carbon nanotube reinforcement of the scarf joint interface, the following recommendations are proposed for future research. These recommendations will corroborate the results of this research and will improve the practicality of carbon nanotube reinforcement for the United States Navy’s composite construction programs.

1. Tension and Shear Testing

Composites can exhibit different characteristics in tension compared to compression. The same could be stated regarding shear characteristics. A detailed study could be developed addressing these strength components and would allow for variations in test configuration. The study could encompass more in depth testing of surface area concentration as well as varying the type of scarf joint developed. This research focused only on the Step-Step scarf joint interface. Similar studies could be performed on Bevel-Step and Bevel-Bevel scarf joint interfaces.

2. Computer Modeling

Computer modeling of carbon nanotube reinforced scarf joint interfaces could prove extremely beneficial. The study could use molecular dynamics to predict potential strength enhancements of carbon nanotube reinforced scarf joint interfaces. The unique benefit of a computer modeling research topic is that the matrix material and the joint configuration can be varied with relative ease and considerably less cost compared to manual composite construction and testing. The product could provide the Navy with a cost effective tool to predict the ideal type of reinforced composite structure.

3. Application Method

To advance carbon nanotube reinforcement for practical use in United States Navy applications further studies must focus on the application method at the joint interface. The methods used in this study are impractical for the U.S. Navy’s VARTM/SCRIMP methods for large scale composite construction. The study must identify a feasible application method that will keep the carbon nanotubes in place during vacuum infusion while maintaining the structural benefits of the reinforcement. The study should also explore more effective dispersion methods by identifying optimal orientation and concentration consistency. The topic has the potential to further enhance the improved scarf joint interface bonding strength identified by this research.

One possible solution to the difficulties associated with CNT application, while using VARTM/SCRIMP methods for composite construction, is the dispersion of CNTs in an adhesive. The CNT-adhesive mixture could then be applied to

the fabric during the dry layup. The adhesive could keep the CNTs in the application region throughout the infusion process.

4. Construction Method

The failure of Group D along the alternate line of fracture, shown in Figures 27, 28, and 29, was most likely caused by fiber buckling. This failure was the result of the carbon fiber step-down that is attributed to Method 1 construction, shown in Figure 2. The failure stress results from Group D do not show the interface strength since failure did not occur at the interface. In order to determine the actual joint interface strength increase of Group D, the test specimens should be constructed via Method 2. Method 2 construction, shown in Figure 2, would eliminate the carbon fiber step-down, and should allow the composite joint to fail along the interface. The other groups would also have to be constructed in order to provide a basis for comparison with Group D, since Method 1 and Method 2 can possess different strength characteristics.

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APPENDIX A: PHASE 1 DATA

A-1. Non-Reinforced Test Data

Plain 01			Plain 02			Plain 03		
Maximum Stress = 127.46			Maximum Stress = 130.70			Maximum Stress = 135.93		
Point	Stress	Strain	Point	Stress	Strain	Point	Stress	Strain
1	-0.1	0	1	-0.129	0	1	-0.114	0
2	-0.103	0	2	-0.132	0	2	-0.116	0
3	-0.093	0	3	-0.127	0	3	-0.115	0
4	-0.091	0	4	-0.105	0.01	4	-0.097	0.018
5	-0.066	0.031	5	-0.099	0.044	5	-0.107	0.053
6	-0.069	0.071	6	-0.075	0.082	6	-0.112	0.09
7	-0.066	0.115	7	-0.068	0.117	7	-0.11	0.127
8	-0.068	0.159	8	-0.031	0.155	8	-0.104	0.163
9	-0.062	0.201	9	0.001	0.19	9	-0.101	0.2
10	-0.048	0.243	10	0.098	0.226	10	-0.092	0.235
11	-0.049	0.285	11	0.183	0.262	11	-0.088	0.272
12	-0.048	0.325	12	0.385	0.298	12	-0.053	0.307
13	-0.024	0.367	13	0.971	0.332	13	0.343	0.343
14	0.02	0.409	14	1.966	0.367	14	1.398	0.379
15	0.581	0.45	15	2.902	0.403	15	2.441	0.414
16	1.775	0.492	16	3.901	0.437	16	3.607	0.45
17	2.848	0.532	17	4.969	0.471	17	5.007	0.485
18	3.954	0.574	18	6.233	0.507	18	6.545	0.52
19	5.238	0.615	19	7.601	0.542	19	8.133	0.554
20	6.614	0.655	20	9.114	0.577	20	9.343	0.589
21	8.027	0.697	21	10.683	0.612	21	11.13	0.624
22	9.457	0.738	22	12.197	0.646	22	13.116	0.658
23	10.844	0.778	23	13.579	0.682	23	15.153	0.693
24	11.979	0.819	24	14.852	0.717	24	17.214	0.728
25	12.689	0.861	25	15.918	0.751	25	19.28	0.763
26	14.232	0.9	26	16.435	0.785	26	21.289	0.797
27	15.951	0.94	27	17.601	0.82	27	23.258	0.832
28	17.79	0.981	28	19.153	0.854	28	25.132	0.867
29	19.647	1.023	29	20.798	0.889	29	26.947	0.902
30	21.765	1.062	30	22.524	0.923	30	28.765	0.936
31	24.105	1.104	31	24.316	0.958	31	30.558	0.971
32	26.229	1.144	32	26.119	0.993	32	32.345	1.004
33	28.178	1.184	33	27.966	1.028	33	34.122	1.039
34	29.986	1.225	34	30.035	1.062	34	35.975	1.072
35	31.791	1.265	35	32.209	1.097	35	37.814	1.107
36	33.618	1.306	36	34.342	1.131	36	39.891	1.142
37	35.415	1.346	37	36.414	1.164	37	41.968	1.177
38	37.141	1.387	38	38.403	1.199	38	43.956	1.211
39	38.779	1.427	39	40.346	1.233	39	45.77	1.246
40	40.353	1.466	40	42.195	1.268	40	47.473	1.281
41	41.837	1.506	41	43.916	1.302	41	49.168	1.315
42	43.358	1.547	42	45.642	1.336	42	50.84	1.349
43	44.957	1.587	43	47.33	1.371	43	52.512	1.383
44	46.566	1.628	44	48.998	1.404	44	54.153	1.418
45	48.255	1.668	45	50.648	1.44	45	55.767	1.453
46	50.095	1.709	46	52.252	1.473	46	57.357	1.488
47	52.028	1.749	47	53.86	1.507	47	58.909	1.522
48	54.115	1.79	48	55.466	1.542	48	60.374	1.557
49	56.3	1.83	49	57.099	1.576	49	61.881	1.592
50	58.507	1.869	50	58.751	1.611	50	63.478	1.628
51	60.652	1.91	51	60.397	1.645	51	65.138	1.663
52	62.832	1.95	52	62.076	1.678	52	66.962	1.696
53	65.093	1.99	53	63.781	1.712	53	68.974	1.731
54	67.302	2.031	54	65.64	1.745	54	71.138	1.765
55	69.572	2.071	55	67.628	1.78	55	73.435	1.8
56	71.807	2.112	56	69.719	1.814	56	75.802	1.835
57	73.705	2.151	57	71.902	1.849	57	78.229	1.87
58	75.623	2.193	58	74.077	1.883	58	80.69	1.904
59	77.606	2.231	59	76.336	1.918	59	83.166	1.939
60	79.389	2.274	60	78.66	1.952	60	85.655	1.974
61	81.08	2.312	61	80.97	1.985	61	88.132	2.008
62	82.648	2.353	62	83.354	2.02	62	90.643	2.043
63	83.991	2.393	63	85.657	2.054	63	93.101	2.078
64	85.448	2.434	64	87.996	2.088	64	95.532	2.113
65	86.766	2.474	65	90.315	2.123	65	97.924	2.147
66	87.507	2.513	66	92.636	2.157	66	100.31	2.182
67	88.179	2.553	67	94.917	2.192	67	102.66	2.217
68	89.231	2.594	68	97.153	2.226	68	105.02	2.252
69	90.47	2.634	69	99.287	2.261	69	107.37	2.286
70	91.741	2.675	70	101.43	2.295	70	109.7	2.321

71	92.904	2.715	71	103.51	2.33	71	111.94	2.356
72	93.996	2.756	72	105.51	2.364	72	114.17	2.39
73	95.01	2.796	73	107.43	2.398	73	116.32	2.425
74	95.877	2.837	74	109.19	2.433	74	118.35	2.46
75	96.424	2.877	75	110.99	2.467	75	120.29	2.495
76	96.564	2.917	76	112.71	2.502	76	122.14	2.529
77	96.241	2.958	77	114.37	2.536	77	123.85	2.564
78	96.117	2.998	78	115.97	2.571	78	125.48	2.599
79	96.113	3.039	79	117.48	2.605	79	126.99	2.633
80	96.254	3.079	80	118.93	2.639	80	128.31	2.668
81	96.781	3.12	81	120.24	2.674	81	129.59	2.703
82	97.338	3.162	82	121.56	2.708	82	130.82	2.736
83	97.843	3.202	83	122.75	2.743	83	132.01	2.771
84	98.341	3.243	84	123.93	2.777	84	133.13	2.806
85	98.672	3.283	85	125.1	2.812	85	134.14	2.84
86	98.994	3.324	86	126.27	2.846	86	135.09	2.875
87	99.357	3.364	87	127.42	2.88	87	135.93	2.91
88	99.735	3.405	88	128.57	2.915	88	12.02	2.946
89	100.2	3.445	89	129.69	2.949	89	2.729	2.977
90	100.56	3.485	90	130.7	2.984	90	3.541	3.011
91	100.72	3.526	91	0.101	3.007	91	4.349	3.046
92	100.93	3.566				92	5.185	3.081
93	101.19	3.607				93	6.045	3.115
94	101.63	3.647				94	6.936	3.15
95	102.22	3.688				95	7.795	3.183
96	102.94	3.728				96	8.6	3.218
97	103.77	3.769				97	9.365	3.253
98	104.61	3.807				98	10.063	3.288
99	105.39	3.848				99	10.717	3.322
100	106.01	3.888				100	11.309	3.356
101	106.58	3.929				101	11.836	3.39
102	107.25	3.969				102	12.28	3.425
103	107.8	4.01				103	12.653	3.46
104	108.44	4.05				104	12.959	3.495
105	109.12	4.091				105	13.252	3.529
106	109.75	4.131				106	13.415	3.564
107	110.5	4.17				107	13.519	3.599
108	111.18	4.21				108	13.694	3.634
109	111.8	4.251				109	13.776	3.668
110	112.36	4.291				110	13.869	3.703
111	112.74	4.332				111	13.967	3.736
112	113.27	4.372				112	14.117	3.771
113	113.9	4.413				113	14.279	3.806
114	114.58	4.451				114	14.225	3.84
115	115.29	4.492				115	14.35	3.875
116	116.05	4.532				116	14.459	3.91
117	116.6	4.573				117	14.571	3.945
118	117.14	4.613				118	14.64	3.979
119	117.62	4.654				119	14.631	4.014
120	118.12	4.694				120	14.639	4.05
121	118.55	4.735				121	14.708	4.085
122	118.76	4.774				122	14.83	4.12
123	118.89	4.814				123	14.905	4.154
124	119.04	4.854				124	14.986	4.189
125	119.2	4.895				125	15.044	4.224
126	119.35	4.937				126	15.068	4.258
127	119.65	4.976				127	15.094	4.293
128	120.24	5.018				128	15.147	4.328
129	120.87	5.058				129	15.165	4.363
130	121.4	5.099				130	15.132	4.397
131	121.84	5.139				131	15.066	4.432
132	122.22	5.18				132	14.991	4.468
133	122.36	5.22				133	14.979	4.503
134	122.66	5.261				134	14.999	4.538
135	123.01	5.301				135	15.04	4.572
136	123.21	5.341				136	15.049	4.607
137	123.09	5.382				137	15.069	4.642
138	122.83	5.422				138	15.038	4.677
139	122.12	5.463				139	14.916	4.711
140	121.82	5.503				140	14.858	4.746
141	121.87	5.544				141	14.799	4.779
142	122.29	5.586				142	14.767	4.814
143	122.65	5.626				143	14.73	4.849
144	122.98	5.667						
145	123.17	5.707						
146	123.31	5.748						
147	123.53	5.788						
148	123.68	5.828						
149	123.1	5.869						
150	122.58	5.909						
151	122.15	5.95						

152	122.24	5.99						
153	122.66	6.031						
154	123.19	6.071						
155	123.77	6.112						
156	124.22	6.152						
157	124.54	6.193						
158	124.86	6.233						
159	125.21	6.274						
160	125.53	6.314						
161	125.76	6.354						
162	126.07	6.393						
163	126.4	6.434						
164	126.75	6.474						
165	126.98	6.515						
166	126.94	6.557						
167	126.96	6.595						
168	127.22	6.636						
169	127.46	6.676						
170	127.37	6.717						
171	126.83	6.757						

A-2. CNT Reinforced Test Data (Acetone)

Acetone 01			Acetone 02			Acetone 04		
Maximum Stress (MPa) = 135.59			Maximum Stress (MPa) = 132.15			Modulus of Elasticity (Mpa) = 63.94		
Pt	Stress	Strain	Pt	Stress	Strain	Pt	Stress	Strain
1	0.179	0	1	-0.295	0	1	0.236	0
2	0.179	0	2	-0.292	0	2	0.231	0
3	0.183	0	3	-0.298	0	3	0.23	0
4	0.617	0.017	4	-0.243	0.004	4	0.358	0.009
5	1.682	0.052	5	0.216	0.037	5	0.472	0.044
6	2.88	0.089	6	0.212	0.072	6	0.691	0.081
7	4.155	0.125	7	0.194	0.108	7	1.441	0.117
8	5.522	0.161	8	0.177	0.146	8	2.394	0.154
9	6.98	0.197	9	0.176	0.182	9	3.461	0.19
10	8.454	0.232	10	0.247	0.217	10	4.624	0.226
11	9.689	0.268	11	0.621	0.253	11	5.822	0.263
12	10.772	0.304	12	1.839	0.288	12	7.093	0.297
13	11.941	0.338	13	3.605	0.323	13	8.464	0.333
14	13.234	0.374	14	5.382	0.358	14	10.22	0.368
15	14.943	0.408	15	7.15	0.392	15	12.143	0.404
16	16.919	0.443	16	8.954	0.428	16	14.029	0.439
17	19.201	0.477	17	10.487	0.463	17	15.748	0.475
18	21.504	0.512	18	11.577	0.497	18	17.092	0.51
19	23.8	0.548	19	13.342	0.533	19	18.104	0.545
20	26.068	0.582	20	15.327	0.567	20	19.075	0.581
21	28.284	0.617	21	17.354	0.603	21	20.244	0.615
22	30.426	0.651	22	19.458	0.638	22	22.088	0.65
23	32.464	0.685	23	21.525	0.672	23	24.08	0.685
24	34.4	0.72	24	23.692	0.708	24	26.13	0.719
25	36.278	0.754	25	25.869	0.742	25	28.46	0.754
26	38.132	0.789	26	28.07	0.777	26	30.935	0.789
27	40.024	0.823	27	30.249	0.811	27	33.487	0.825
28	41.845	0.858	28	32.34	0.845	28	35.998	0.86
29	43.68	0.892	29	34.353	0.88	29	38.468	0.894
30	45.406	0.926	30	36.316	0.914	30	40.906	0.929
31	47.086	0.961	31	38.233	0.949	31	43.269	0.964
32	48.801	0.995	32	40.316	0.983	32	45.559	0.999
33	50.53	1.028	33	42.306	1.018	33	47.692	1.033
34	52.29	1.064	34	44.307	1.052	34	49.744	1.068
35	54.074	1.099	35	46.263	1.087	35	51.803	1.103
36	55.824	1.133	36	48.074	1.121	36	53.829	1.138
37	57.569	1.167	37	49.81	1.155	37	55.839	1.172
38	59.286	1.202	38	51.48	1.19	38	57.841	1.207
39	61.056	1.236	39	53.05	1.224	39	59.884	1.242
40	62.988	1.271	40	54.587	1.259	40	61.965	1.276
41	64.934	1.305	41	56.005	1.293	41	63.995	1.311
42	66.824	1.34	42	57.396	1.326	42	66.061	1.346
43	68.671	1.374	43	59.039	1.361	43	68.111	1.379
44	70.419	1.407	44	60.724	1.395	44	70.155	1.414
45	72.225	1.442	45	62.347	1.43	45	72.251	1.449
46	73.919	1.476	46	63.878	1.464	46	74.318	1.483
47	75.63	1.512	47	65.29	1.498	47	76.39	1.518
48	77.306	1.546	48	66.677	1.533	48	78.493	1.553
49	78.926	1.581	49	67.999	1.566	49	80.562	1.586
50	80.536	1.615	50	69.29	1.6	50	82.717	1.621
51	82.117	1.65	51	70.574	1.635	51	84.929	1.656
52	83.631	1.684	52	71.932	1.669	52	87.148	1.69
53	85.119	1.718	53	73.268	1.702	53	89.518	1.725
54	86.563	1.753	54	74.638	1.737	54	91.956	1.76
55	87.996	1.787	55	76.001	1.771	55	94.423	1.795
56	89.414	1.822	56	77.48	1.806	56	96.976	1.829
57	90.775	1.856	57	79.001	1.84	57	99.547	1.864
58	92.14	1.891	58	80.588	1.874	58	102.14	1.899
59	93.458	1.925	59	82.355	1.907	59	104.74	1.932
60	94.694	1.959	60	84.181	1.942	60	107.29	1.967
61	95.962	1.994	61	86.071	1.976	61	109.9	2
62	97.196	2.028	62	87.976	2.011	62	112.57	2.035
63	98.422	2.063	63	89.9	2.045	63	115.22	2.069
64	99.642	2.097	64	91.864	2.08	64	117.93	2.104
65	100.8	2.132	65	93.865	2.114	65	120.58	2.139
66	101.95	2.166	66	95.9	2.149	66	123.27	2.174
67	103.05	2.2	67	97.927	2.183	67	125.9	2.208
68	104.19	2.234	68	99.884	2.217	68	128.43	2.243
69	105.28	2.268	69	101.79	2.252	69	131.01	2.278
70	106.36	2.302	70	103.66	2.286	70	133.47	2.313
71	107.43	2.337	71	105.46	2.321	71	135.87	2.346
72	108.48	2.371	72	107.23	2.355	72	138.21	2.381
73	109.46	2.406	73	108.97	2.39	73	140.45	2.415
74	110.45	2.44	74	110.68	2.424	74	142.65	2.45
75	111.36	2.475	75	112.25	2.458	75	144.74	2.485
76	112.24	2.508	76	113.86	2.493	76	146.69	2.519
77	113.14	2.542	77	115.44	2.527	77	148.62	2.554
78	114	2.577	78	116.91	2.562	78	150.48	2.589

79	114.84	2.611	79	118.34	2.596	79	152.25	2.624
80	115.63	2.645	80	119.73	2.631	80	153.88	2.66
81	116.41	2.678	81	121.05	2.665	81	155.38	2.693
82	117.17	2.713	82	122.32	2.699	82	156.42	2.729
83	117.91	2.747	83	123.55	2.734	83	157.93	2.764
84	118.59	2.782	84	124.74	2.768	84	0.163	2.75
85	119.25	2.816	85	125.93	2.803			
86	119.86	2.851	86	127.1	2.837			
87	120.5	2.885	87	128.17	2.872			
88	121.11	2.918	88	129.3	2.906			
89	121.7	2.953	89	130.33	2.941			
90	122.25	2.987	90	131.38	2.975			
91	122.78	3.021	91	132.15	3.009			
92	123.27	3.056	92	131.99	3.044			
93	123.8	3.09	93	-0.105	3.074			
94	124.27	3.125						
95	124.78	3.159						
96	125.28	3.194						
97	125.8	3.229						
98	126.29	3.264						
99	126.68	3.298						
100	127.14	3.333						
101	127.56	3.367						
102	127.97	3.4						
103	128.32	3.435						
104	128.72	3.47						
105	129.08	3.505						
106	129.48	3.539						
107	129.88	3.574						
108	130.28	3.608						
109	130.65	3.643						
110	130.98	3.677						
111	131.35	3.711						
112	131.65	3.746						
113	131.96	3.78						
114	132.23	3.815						
115	132.49	3.849						
116	132.77	3.884						
117	133.08	3.919						
118	133.32	3.953						
119	133.6	3.987						
120	133.93	4.023						
121	134.23	4.057						
122	134.55	4.092						
123	134.84	4.126						
124	135.12	4.159						
125	135.44	4.194						
126	135.59	4.228						
127	-0.213	4.272						

A-3. CNT Reinforced Test Data (Ethylene Glycol)

Glycol 02			Glycol 03			Glycol 04		
Maximum Stress (MPa) = 95.56			Maximum Stress (MPa) = 90.85			Maximum Stress = 84.86		
Point	Stress(Mpa)	Strain(%)	Point	Stress(Mpa)	Strain(%)	Point	Stress(Mpa)	Strain(%)
1	-0.167	0	1	-0.156	0	1	0.113	0
2	-0.165	0	2	-0.149	0	2	0.113	0
3	-0.164	0	3	-0.149	0	3	0.108	0
4	-0.096	0.017	4	-0.106	0.007	4	0.121	0.011
5	-0.04	0.054	5	-0.108	0.038	5	0.13	0.045
6	0	0.088	6	-0.108	0.075	6	0.13	0.081
7	0.067	0.125	7	-0.094	0.111	7	0.218	0.117
8	0.156	0.163	8	-0.104	0.148	8	0.841	0.154
9	0.251	0.197	9	-0.095	0.184	9	1.68	0.19
10	0.306	0.234	10	-0.098	0.221	10	2.554	0.225
11	0.355	0.269	11	-0.102	0.256	11	3.568	0.26
12	0.755	0.303	12	-0.094	0.292	12	4.644	0.296
13	1.576	0.339	13	-0.022	0.327	13	5.712	0.332
14	2.549	0.373	14	0.168	0.37	14	6.683	0.367
15	3.806	0.409	15	0.782	0.398	15	7.783	0.402
16	5.308	0.444	16	1.692	0.432	16	9.312	0.437
17	6.866	0.478	17	2.633	0.468	17	11.096	0.471
18	8.504	0.513	18	3.644	0.502	18	12.989	0.506
19	9.845	0.548	19	4.754	0.538	19	14.944	0.541
20	10.37	0.583	20	5.867	0.573	20	16.801	0.576
21	11.524	0.617	21	7.105	0.607	21	18.325	0.612
22	13.416	0.653	22	8.285	0.642	22	19.594	0.646
23	15.325	0.687	23	8.958	0.676	23	20.823	0.68
24	17.219	0.722	24	9.413	0.71	24	22.091	0.715
25	19.064	0.756	25	10.483	0.746	25	23.315	0.749
26	20.79	0.791	26	11.558	0.779	26	24.557	0.784
27	22.4	0.825	27	12.802	0.815	27	25.732	0.818
28	24.115	0.86	28	14.161	0.848	28	27.132	0.853
29	26.334	0.894	29	15.513	0.883	29	28.858	0.888
30	28.421	0.928	30	16.834	0.917	30	30.505	0.921
31	30.098	0.964	31	18.132	0.951	31	32.09	0.956
32	31.53	0.999	32	19.378	0.986	32	33.665	0.99
33	32.896	1.033	33	20.751	1.02	33	35.165	1.025
34	34.276	1.068	34	22.269	1.055	34	36.698	1.059
35	35.665	1.102	35	23.693	1.089	35	38.13	1.094
36	36.975	1.137	36	24.94	1.122	36	39.493	1.128
37	38.329	1.171	37	26.05	1.157	37	40.772	1.163
38	40.054	1.205	38	27.096	1.191	38	41.941	1.197
39	41.964	1.24	39	28.147	1.226	39	43.059	1.231
40	43.837	1.274	40	29.189	1.259	40	44.179	1.266
41	45.599	1.307	41	30.185	1.293	41	45.27	1.299
42	47.314	1.342	42	31.152	1.327	42	46.381	1.332
43	48.98	1.376	43	32.15	1.362	43	47.523	1.366
44	50.564	1.411	44	33.14	1.396	44	48.666	1.401
45	52.129	1.445	45	34.119	1.431	45	49.882	1.435
46	53.621	1.479	46	35.121	1.464	46	51.136	1.47
47	55.07	1.514	47	36.327	1.498	47	52.37	1.504
48	56.502	1.548	48	37.559	1.533	48	53.625	1.539
49	57.953	1.581	49	38.742	1.567	49	54.894	1.572
50	59.387	1.616	50	39.944	1.602	50	56.215	1.606
51	60.749	1.65	51	41.249	1.636	51	57.558	1.641
52	62.068	1.683	52	42.548	1.67	52	58.894	1.675
53	63.329	1.718	53	43.87	1.705	53	60.295	1.709
54	64.576	1.752	54	45.232	1.739	54	61.681	1.744
55	65.786	1.787	55	46.55	1.774	55	63.075	1.778
56	66.956	1.821	56	47.895	1.808	56	64.498	1.813
57	68.074	1.856	57	49.265	1.843	57	65.766	1.847
58	69.217	1.889	58	50.625	1.877	58	66.947	1.882
59	70.365	1.923	59	52.067	1.911	59	67.994	1.916
60	71.549	1.957	60	53.493	1.946	60	68.898	1.95
61	72.76	1.992	61	54.979	1.98	61	69.668	1.986
62	73.971	2.026	62	56.554	2.015	62	70.193	2.021
63	75.192	2.061	63	58.155	2.049	63	70.607	2.054
64	76.446	2.095	64	59.841	2.084	64	71.27	2.088
65	77.707	2.13	65	61.606	2.118	65	72.307	2.123
66	79.028	2.164	66	63.503	2.152	66	73.585	2.157
67	80.415	2.198	67	65.486	2.187	67	75.129	2.191
68	81.827	2.233	68	67.603	2.221	68	76.91	2.226
69	83.309	2.267	69	69.827	2.256	69	78.907	2.26
70	84.845	2.302	70	72.118	2.29	70	80.914	2.295
71	86.482	2.336	71	74.421	2.325	71	82.927	2.329
72	88.169	2.371	72	76.791	2.359	72	84.869	2.364
73	89.912	2.405	73	79.148	2.394	73	31.648	2.397
74	91.761	2.44	74	81.506	2.428	74	0	2.416
75	93.656	2.474	75	83.905	2.462			
76	95.565	2.508	76	86.288	2.497			

77	87.034	2.543	77	88.596	2.531			
78	-0.213	2.552	78	90.855	2.566			

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APPENDIX B: PHASE 2 DATA

B-1. Non-Reinforced Test Data

0.00g CNT (01)			0.00g CNT (02)			0.00g CNT (04)			0.00g CNT (05)		
Maximum Stress =		162.71	Maximum Stress =		146.73	Maximum Stress =		163.36	Maximum Stress =		165.29
Point	Strain(%)	Stress	Point	Strain(%)	Stress	Point	Strain(%)	Stress	Point	Strain(%)	Stress
1	0.000	1.833	1	0.000	0.090	1	0.000	0.616	1	0.000	0.595
2	0.000	1.826	2	0.000	0.091	2	0.000	0.619	2	0.000	0.591
3	0.000	1.832	3	0.000	0.087	3	0.000	0.636	3	0.000	0.586
4	0.015	2.622	4	0.017	0.111	4	0.004	0.788	4	0.004	0.693
5	0.052	4.448	5	0.054	0.458	5	0.037	1.637	5	0.038	1.567
6	0.090	6.380	6	0.090	1.519	6	0.073	2.386	6	0.075	2.911
7	0.126	8.488	7	0.129	2.735	7	0.109	3.367	7	0.112	4.221
8	0.162	10.755	8	0.165	4.014	8	0.145	4.477	8	0.148	5.525
9	0.197	12.972	9	0.202	5.397	9	0.180	5.829	9	0.185	6.961
10	0.234	15.342	10	0.239	6.860	10	0.216	7.374	10	0.222	8.599
11	0.270	17.831	11	0.274	8.429	11	0.251	9.200	11	0.258	10.454
12	0.305	20.305	12	0.311	10.152	12	0.286	11.230	12	0.294	12.165
13	0.342	22.955	13	0.347	11.892	13	0.322	13.377	13	0.329	14.195
14	0.377	25.574	14	0.381	13.583	14	0.357	15.614	14	0.366	16.322
15	0.412	28.166	15	0.418	15.323	15	0.392	17.972	15	0.401	18.730
16	0.448	30.853	16	0.455	16.898	16	0.426	20.165	16	0.438	21.273
17	0.483	33.514	17	0.490	18.256	17	0.461	22.751	17	0.473	23.866
18	0.518	36.252	18	0.525	19.583	18	0.496	25.633	18	0.508	26.417
19	0.555	39.035	19	0.561	21.137	19	0.530	28.411	19	0.545	28.987
20	0.588	41.762	20	0.596	23.071	20	0.566	31.434	20	0.581	31.445
21	0.625	44.647	21	0.631	25.071	21	0.601	34.420	21	0.616	33.963
22	0.660	47.520	22	0.667	27.092	22	0.635	37.462	22	0.653	36.572
23	0.695	50.368	23	0.702	29.202	23	0.669	40.597	23	0.688	39.135
24	0.730	53.323	24	0.737	31.361	24	0.704	43.572	24	0.723	41.740
25	0.765	56.195	25	0.771	33.514	25	0.738	46.641	25	0.758	44.326
26	0.800	59.111	26	0.808	35.754	26	0.773	49.676	26	0.794	46.934
27	0.835	62.020	27	0.842	37.959	27	0.806	52.585	27	0.829	49.571
28	0.870	64.863	28	0.877	40.207	28	0.840	55.588	28	0.864	52.180
29	0.905	67.771	29	0.913	42.483	29	0.875	58.437	29	0.900	54.804
30	0.941	70.605	30	0.948	44.641	30	0.909	61.175	30	0.935	57.457
31	0.976	73.364	31	0.983	46.887	31	0.944	63.945	31	0.970	60.108
32	1.011	76.172	32	1.018	49.103	32	0.977	66.525	32	1.006	62.813
33	1.046	78.883	33	1.054	51.334	33	1.011	69.167	33	1.041	65.483
34	1.081	81.597	34	1.089	53.472	34	1.046	71.747	34	1.076	68.168
35	1.116	84.302	35	1.124	55.511	35	1.079	74.215	35	1.112	70.899
36	1.151	86.837	36	1.160	57.754	36	1.114	76.748	36	1.147	73.599
37	1.186	89.439	37	1.195	60.006	37	1.149	79.134	37	1.182	76.381
38	1.221	91.955	38	1.229	62.235	38	1.182	81.374	38	1.218	79.214
39	1.256	94.333	39	1.264	64.564	39	1.218	83.667	39	1.251	82.023
40	1.291	96.771	40	1.300	66.920	40	1.251	85.805	40	1.287	84.933
41	1.326	99.079	41	1.335	69.307	41	1.287	87.968	41	1.322	87.846
42	1.361	101.370	42	1.370	71.680	42	1.321	90.060	42	1.357	90.826
43	1.396	103.670	43	1.407	74.084	43	1.354	91.976	43	1.393	93.876
44	1.430	105.840	44	1.442	76.548	44	1.390	93.942	44	1.428	96.876
45	1.466	108.040	45	1.476	79.014	45	1.424	95.838	45	1.462	99.875
46	1.500	110.220	46	1.511	81.420	46	1.459	97.673	46	1.497	102.890
47	1.535	112.310	47	1.547	83.938	47	1.493	99.525	47	1.533	105.820
48	1.570	114.390	48	1.582	86.389	48	1.528	101.220	48	1.568	108.850
49	1.604	116.380	49	1.617	88.958	49	1.562	103.060	49	1.603	111.770
50	1.639	118.340	50	1.653	91.556	50	1.598	104.880	50	1.638	114.780
51	1.674	120.280	51	1.688	94.225	51	1.631	106.560	51	1.674	117.850
52	1.707	122.090	52	1.723	96.973	52	1.667	108.350	52	1.708	120.820
53	1.744	123.910	53	1.759	99.789	53	1.700	110.050	53	1.743	123.840
54	1.779	125.490	54	1.792	102.660	54	1.734	111.670	54	1.778	126.890
55	1.814	127.090	55	1.829	105.590	55	1.769	113.280	55	1.814	129.860
56	1.849	128.760	56	1.864	108.520	56	1.803	114.790	56	1.849	132.810
57	1.884	130.320	57	1.898	111.470	57	1.839	116.430	57	1.884	135.650
58	1.917	131.760	58	1.934	114.470	58	1.873	117.940	58	1.920	138.460
59	1.952	133.370	59	1.969	117.490	59	1.906	119.290	59	1.955	141.140
60	1.987	134.790	60	2.004	120.470	60	1.942	120.810	60	1.990	143.730
61	2.022	136.310	61	2.040	123.450	61	1.975	122.200	61	2.025	146.220
62	2.058	137.770	62	2.075	126.380	62	2.010	123.510	62	2.059	148.660
63	2.092	139.180	63	2.110	129.360	63	2.044	124.800	63	2.095	151.010
64	2.128	140.580	64	2.146	132.260	64	2.079	125.890	64	2.130	153.290
65	2.163	141.890	65	2.181	135.100	65	2.113	127.170	65	2.165	155.390
66	2.198	143.260	66	2.218	137.850	66	2.147	128.340	66	2.201	157.480
67	2.233	144.620	67	2.253	140.360	67	2.182	129.340	67	2.236	159.440
68	2.266	145.880	68	2.288	142.880	68	2.216	130.320	68	2.271	161.240
69	2.303	147.240	69	2.324	145.270	69	2.252	131.260	69	2.307	162.810
70	2.338	148.560	70	2.359	146.730	70	2.285	132.140	70	2.342	164.360
71	2.373	149.830				71	2.321	133.080	71	2.376	165.290
72	2.408	151.140				72	2.354	133.900			

73	2.441	152.290				73	2.390	134.930			
74	2.476	153.550				74	2.423	135.930			
75	2.511	154.720				75	2.457	136.870			
76	2.546	155.790				76	2.492	137.860			
77	2.581	156.870				77	2.526	138.690			
78	2.616	157.940				78	2.561	139.550			
79	2.651	158.870				79	2.595	140.430			
80	2.685	159.780				80	2.628	141.220			
81	2.720	160.670				81	2.664	142.040			
82	2.756	161.450				82	2.698	142.690			
83	2.791	162.200				83	2.731	143.260			
84	2.825	162.710				84	2.767	144.080			
						85	2.800	144.820			
						86	2.835	145.540			
						87	2.869	146.160			
						88	2.902	146.700			
						89	2.937	147.300			
						90	2.971	147.780			
						91	3.006	148.230			
						92	3.040	148.780			
						93	3.074	149.270			
						94	3.109	149.690			
						95	3.143	150.200			
						96	3.178	150.480			
						97	3.212	151.010			
						98	3.247	151.500			
						99	3.281	151.890			
						100	3.315	152.380			
						101	3.350	152.760			
						102	3.384	153.010			
						103	3.419	153.470			
						104	3.453	153.790			
						105	3.488	154.140			
						106	3.522	154.410			
						107	3.556	154.660			
						108	3.591	155.110			
						109	3.625	155.530			
						110	3.660	156.030			
						111	3.694	156.560			
						112	3.729	156.940			
						113	3.763	157.500			
						114	3.798	157.980			
						115	3.831	158.350			
						116	3.866	158.930			
						117	3.901	159.410			
						118	3.935	159.860			
						119	3.970	160.420			
						120	4.004	160.880			
						121	4.040	161.540			
						122	4.074	162.150			
						123	4.107	162.530			
						124	4.143	163.100			
						125	4.178	163.360			

B-2. 7.5g/m^2 CNT Reinforced Test Data

0.10g CNT (01)			0.10g CNT (02)			0.10g CNT (04)			0.10g CNT (05)		
Maximum Stress =		187.06	Maximum Stress =		176.39	Maximum Stress) =		174.62	Maximum Stress =		167.82
Point	Strain(%)	Stress	Point	Strain(%)	Stress	Point	Strain(%)	Stress	Point	Strain(%)	Stress
1	0.000	0.031	1	0.000	0.134	1	0.000	-0.013	1	0.000	-0.104
2	0.000	0.032	2	0.000	0.143	2	0.000	0.000	2	0.000	-0.123
3	0.000	0.027	3	0.000	0.146	3	0.000	-0.018	3	0.000	-0.108
4	0.019	0.042	4	0.003	0.148	4	0.020	0.239	4	0.017	0.216
5	0.055	0.231	5	0.031	0.907	5	0.054	0.279	5	0.054	0.231
6	0.092	1.460	6	0.069	1.884	6	0.092	0.274	6	0.089	0.221
7	0.129	2.811	7	0.106	3.145	7	0.127	0.899	7	0.127	0.703
8	0.165	4.109	8	0.143	4.510	8	0.163	2.004	8	0.164	2.060
9	0.202	5.548	9	0.181	6.035	9	0.200	3.127	9	0.199	3.360
10	0.238	7.215	10	0.216	7.597	10	0.235	4.376	10	0.236	4.849
11	0.273	8.953	11	0.251	9.404	11	0.271	5.712	11	0.273	6.458
12	0.309	10.932	12	0.290	11.496	12	0.308	7.111	12	0.308	7.996
13	0.345	13.125	13	0.325	13.420	13	0.343	8.470	13	0.345	9.709
14	0.381	15.166	14	0.360	15.150	14	0.379	9.982	14	0.381	11.459
15	0.417	17.375	15	0.397	16.793	15	0.414	11.261	15	0.415	13.200
16	0.452	19.789	16	0.432	18.887	16	0.449	12.643	16	0.452	15.170
17	0.487	22.356	17	0.469	21.478	17	0.483	13.587	17	0.487	16.959
18	0.522	24.987	18	0.504	24.210	18	0.518	14.563	18	0.523	18.943
19	0.558	27.541	19	0.540	26.963	19	0.553	15.799	19	0.558	21.099
20	0.592	30.237	20	0.576	29.794	20	0.588	17.881	20	0.593	22.905
21	0.629	32.862	21	0.612	32.598	21	0.622	20.111	21	0.629	24.774
22	0.662	35.497	22	0.647	35.392	22	0.657	22.523	22	0.665	26.768
23	0.699	38.248	23	0.682	38.122	23	0.692	24.909	23	0.699	29.257
24	0.734	40.904	24	0.718	40.826	24	0.726	27.225	24	0.736	31.905
25	0.769	43.611	25	0.753	43.543	25	0.761	29.652	25	0.771	34.444
26	0.805	46.264	26	0.788	46.164	26	0.796	31.980	26	0.807	36.968
27	0.839	48.747	27	0.823	48.703	27	0.831	34.326	27	0.842	39.533
28	0.875	51.363	28	0.860	51.276	28	0.865	36.602	28	0.877	41.968
29	0.910	53.870	29	0.896	53.699	29	0.900	38.876	29	0.912	44.450
30	0.945	56.357	30	0.929	56.028	30	0.933	41.153	30	0.948	46.994
31	0.980	58.922	31	0.965	58.358	31	0.968	43.381	31	0.983	49.419
32	1.016	61.386	32	1.000	60.593	32	1.003	45.480	32	1.017	51.927
33	1.050	63.866	33	1.035	62.853	33	1.037	47.612	33	1.052	54.441
34	1.085	66.372	34	1.069	65.038	34	1.071	49.763	34	1.089	56.929
35	1.121	68.717	35	1.105	67.221	35	1.106	51.912	35	1.124	59.505
36	1.156	71.164	36	1.141	69.435	36	1.140	54.084	36	1.160	61.858
37	1.191	73.561	37	1.175	71.455	37	1.175	56.188	37	1.195	64.283
38	1.225	75.937	38	1.210	73.571	38	1.210	58.342	38	1.230	66.804
39	1.261	78.346	39	1.246	75.593	39	1.246	60.451	39	1.266	69.224
40	1.296	80.696	40	1.280	77.532	40	1.279	62.494	40	1.301	71.804
41	1.331	83.123	41	1.317	79.606	41	1.314	64.585	41	1.336	74.244
42	1.364	85.506	42	1.352	81.570	42	1.349	66.568	42	1.371	76.722
43	1.399	87.775	43	1.386	83.464	43	1.383	68.565	43	1.407	79.341
44	1.434	90.156	44	1.422	85.452	44	1.418	70.545	44	1.442	81.722
45	1.468	92.408	45	1.456	87.368	45	1.453	72.486	45	1.477	84.231
46	1.503	94.658	46	1.492	89.297	46	1.488	74.421	46	1.513	86.714
47	1.538	96.939	47	1.527	91.194	47	1.522	76.293	47	1.548	89.042
48	1.573	99.216	48	1.561	93.036	48	1.557	78.127	48	1.583	91.514
49	1.608	101.560	49	1.598	95.030	49	1.592	80.174	49	1.619	93.834
50	1.643	103.930	50	1.633	97.006	50	1.627	82.178	50	1.654	96.178
51	1.677	106.230	51	1.667	98.976	51	1.661	84.252	51	1.691	98.654
52	1.713	108.700	52	1.703	100.990	52	1.696	86.421	52	1.725	100.860
53	1.748	111.040	53	1.739	102.970	53	1.731	88.684	53	1.760	103.350
54	1.782	113.340	54	1.774	105.030	54	1.765	91.029	54	1.795	105.930
55	1.817	115.670	55	1.809	107.150	55	1.800	93.564	55	1.829	108.540
56	1.852	117.920	56	1.843	108.860	56	1.833	96.230	56	1.866	111.430
57	1.887	120.300	57	1.880	110.950	57	1.868	99.049	57	1.900	114.290
58	1.922	122.590	58	1.914	113.110	58	1.903	101.930	58	1.935	117.370
59	1.955	124.770	59	1.949	115.280	59	1.938	104.920	59	1.970	120.710
60	1.992	127.180	60	1.985	117.550	60	1.972	107.880	60	2.004	123.860
61	2.027	129.530	61	2.020	119.560	61	2.008	110.910	61	2.040	127.220
62	2.062	131.840	62	2.055	121.710	62	2.043	113.870	62	2.076	130.620
63	2.097	134.230	63	2.090	123.780	63	2.078	116.820	63	2.110	133.940
64	2.132	136.510	64	2.126	125.940	64	2.113	119.740	64	2.145	137.360
65	2.167	138.730	65	2.161	128.300	65	2.147	122.670	65	2.181	140.640
66	2.202	140.980	66	2.196	130.590	66	2.182	125.510	66	2.216	144.020
67	2.235	143.090	67	2.232	132.860	67	2.217	128.280	67	2.251	147.460
68	2.272	145.320	68	2.267	135.190	68	2.251	131.020	68	2.285	150.630
69	2.307	147.370	69	2.301	137.510	69	2.286	133.670	69	2.321	153.910
70	2.340	149.380	70	2.338	139.970	70	2.321	136.230	70	2.356	157.100
71	2.375	151.630	71	2.372	142.430	71	2.356	138.640	71	2.391	160.070
72	2.409	153.750	72	2.407	144.820	72	2.390	141.000	72	2.427	162.950
73	2.445	155.960	73	2.442	147.200	73	2.425	143.300	73	2.462	165.600
74	2.480	158.050	74	2.477	149.440	74	2.460	145.490	74	2.497	167.820
75	2.515	160.120	75	2.514	151.650	75	2.494	147.550			
76	2.550	162.240	76	2.550	153.850	76	2.529	149.510			

77	2.585	164.170	77	2.585	155.890	77	2.563	151.460			
78	2.619	166.120	78	2.620	157.990	78	2.597	153.320			
79	2.656	168.070	79	2.655	160.000	79	2.632	155.150			
80	2.689	169.890	80	2.691	161.900	80	2.667	156.970			
81	2.724	171.840	81	2.726	163.760	81	2.701	158.700			
82	2.759	173.630	82	2.761	165.380	82	2.735	160.340			
83	2.794	175.240	83	2.797	166.980	83	2.769	161.900			
84	2.831	176.840	84	2.832	168.540	84	2.804	163.290			
85	2.866	178.270	85	2.867	169.840	85	2.839	164.720			
86	2.901	179.570	86	2.903	170.940	86	2.874	166.090			
87	2.937	180.710	87	2.938	171.940	87	2.908	167.290			
88	2.971	181.150	88	2.973	172.930	88	2.943	168.420			
89	3.007	182.220	89	3.009	173.910	89	2.978	169.480			
90	3.042	182.750	90	3.044	174.690	90	3.013	170.400			
91	3.076	183.770	91	3.079	175.570	91	3.047	171.310			
92	3.112	184.710	92	3.114	176.390	92	3.081	172.080			
93	3.147	185.400				93	3.115	172.880			
94	3.181	186.020				94	3.150	173.630			
95	3.217	186.630				95	3.185	174.180			
96	3.251	187.060				96	3.219	174.620			

B-3. 11.5g/m^2 CNT Reinforced Test Data

0.15g CNT (01)			0.15g CNT (03)			0.15g CNT (04)			0.15g CNT (05)		
Maximum Stress =		166.20	Maximum Stress =		165.60	Maximum Stress =		180.42	Maximum Stress =		161.12
Point	Strain(%)	Stress	Point	Strain(%)	Stress	Point	Strain(%)	Stress	Point	Strain(%)	Stress
1	0.000	0.013	1	0.000	0.480	1	0.000	-0.103	1	0.000	-0.137
2	0.000	0.007	2	0.000	0.482	2	0.000	-0.090	2	0.000	-0.145
3	0.000	0.007	3	0.000	0.481	3	0.000	-0.092	3	0.000	-0.131
4	0.027	0.056	4	0.017	1.198	4	0.004	0.109	4	0.013	0.474
5	0.063	0.050	5	0.054	2.443	5	0.038	1.989	5	0.048	1.100
6	0.099	0.055	6	0.092	3.796	6	0.074	2.692	6	0.084	1.216
7	0.136	0.625	7	0.129	5.094	7	0.110	3.553	7	0.121	1.579
8	0.172	1.959	8	0.165	6.251	8	0.147	4.747	8	0.157	2.339
9	0.207	3.411	9	0.202	7.429	9	0.182	5.966	9	0.195	3.786
10	0.244	4.763	10	0.239	8.724	10	0.218	7.407	10	0.230	5.438
11	0.279	6.122	11	0.275	10.110	11	0.254	9.195	11	0.268	7.002
12	0.315	7.646	12	0.311	11.604	12	0.289	11.076	12	0.303	8.605
13	0.350	9.075	13	0.346	13.087	13	0.325	12.934	13	0.339	10.343
14	0.385	10.674	14	0.383	14.990	14	0.360	14.477	14	0.375	12.251
15	0.420	12.777	15	0.419	17.035	15	0.394	15.623	15	0.411	14.516
16	0.455	15.004	16	0.455	18.663	16	0.432	16.955	16	0.445	16.865
17	0.492	17.495	17	0.490	20.359	17	0.467	19.109	17	0.480	19.157
18	0.527	19.980	18	0.525	22.249	18	0.501	21.365	18	0.515	21.175
19	0.562	22.146	19	0.561	24.761	19	0.536	23.673	19	0.552	23.110
20	0.598	24.238	20	0.596	27.240	20	0.571	25.854	20	0.587	25.003
21	0.633	26.781	21	0.631	29.623	21	0.606	28.126	21	0.622	27.584
22	0.668	28.988	22	0.667	32.014	22	0.640	30.320	22	0.657	30.269
23	0.703	30.910	23	0.702	34.405	23	0.675	32.497	23	0.691	32.854
24	0.738	32.700	24	0.737	36.657	24	0.711	34.765	24	0.727	35.523
25	0.773	34.726	25	0.773	39.009	25	0.746	36.948	25	0.762	38.093
26	0.808	37.459	26	0.808	41.335	26	0.781	39.143	26	0.796	40.612
27	0.843	40.147	27	0.843	43.616	27	0.817	41.328	27	0.832	43.310
28	0.878	42.912	28	0.878	45.919	28	0.850	43.398	28	0.866	45.831
29	0.913	45.602	29	0.913	48.131	29	0.886	45.595	29	0.900	48.391
30	0.948	48.250	30	0.949	50.416	30	0.921	47.760	30	0.936	50.936
31	0.985	50.977	31	0.984	52.662	31	0.954	49.914	31	0.969	53.345
32	1.018	53.566	32	1.018	54.847	32	0.989	52.116	32	1.004	55.839
33	1.055	56.247	33	1.054	57.144	33	1.024	54.180	33	1.039	58.232
34	1.090	58.919	34	1.089	59.423	34	1.058	56.368	34	1.073	60.633
35	1.123	61.466	35	1.124	61.710	35	1.093	58.651	35	1.109	63.142
36	1.158	64.165	36	1.160	64.127	36	1.126	60.896	36	1.143	65.569
37	1.195	66.802	37	1.195	66.404	37	1.163	63.193	37	1.179	67.991
38	1.228	69.367	38	1.229	68.792	38	1.197	65.534	38	1.214	70.400
39	1.265	72.000	39	1.266	71.167	39	1.231	67.781	39	1.249	72.616
40	1.298	74.525	40	1.299	73.500	40	1.265	70.048	40	1.284	74.896
41	1.335	77.195	41	1.336	75.878	41	1.300	72.260	41	1.319	77.109
42	1.370	79.743	42	1.372	78.199	42	1.335	74.586	42	1.353	79.193
43	1.405	82.197	43	1.407	80.492	43	1.369	76.971	43	1.389	81.327
44	1.440	84.789	44	1.442	82.816	44	1.404	79.298	44	1.423	83.320
45	1.475	87.238	45	1.476	85.030	45	1.439	81.684	45	1.458	85.187
46	1.510	89.727	46	1.513	87.454	46	1.472	84.061	46	1.493	86.980
47	1.545	92.252	47	1.548	89.783	47	1.506	86.452	47	1.528	88.605
48	1.580	94.684	48	1.582	92.023	48	1.540	89.002	48	1.563	90.254
49	1.615	97.185	49	1.617	94.284	49	1.575	91.579	49	1.598	91.733
50	1.650	99.722	50	1.653	96.470	50	1.610	94.225	50	1.633	93.203
51	1.685	102.060	51	1.688	98.534	51	1.644	97.013	51	1.668	94.647
52	1.720	104.550	52	1.723	100.650	52	1.679	99.880	52	1.703	95.984
53	1.755	106.930	53	1.759	102.760	53	1.714	102.940	53	1.738	97.312
54	1.790	109.290	54	1.794	104.920	54	1.749	106.020	54	1.773	98.491
55	1.825	111.710	55	1.828	106.950	55	1.783	109.140	55	1.808	99.422
56	1.859	114.050	56	1.863	109.040	56	1.818	112.320	56	1.843	100.370
57	1.894	116.460	57	1.900	111.180	57	1.853	115.470	57	1.878	101.160
58	1.929	118.780	58	1.934	113.260	58	1.888	118.640	58	1.912	102.070
59	1.962	121.000	59	1.970	115.450	59	1.922	121.840	59	1.948	103.120
60	1.999	123.360	60	2.006	117.640	60	1.957	124.950	60	1.983	104.190
61	2.032	125.550	61	2.040	119.800	61	1.992	128.270	61	2.018	105.190
62	2.067	127.860	62	2.076	122.320	62	2.026	131.600	62	2.053	106.030
63	2.102	130.220	63	2.110	124.850	63	2.060	134.940	63	2.088	106.740
64	2.136	132.540	64	2.145	127.520	64	2.096	138.350	64	2.125	107.810
65	2.171	134.960	65	2.182	130.260	65	2.131	141.630	65	2.160	108.920
66	2.206	137.370	66	2.218	132.960	66	2.165	144.860	66	2.193	110.090
67	2.241	139.670	67	2.253	135.780	67	2.200	148.060	67	2.230	111.380
68	2.276	142.140	68	2.288	138.540	68	2.235	151.080	68	2.265	112.530
69	2.311	144.470	69	2.324	141.260	69	2.270	154.070	69	2.300	113.970
70	2.346	146.820	70	2.359	144.060	70	2.303	156.810	70	2.335	115.700
71	2.381	149.200	71	2.394	146.710	71	2.338	159.440	71	2.368	117.550
72	2.416	151.410	72	2.429	149.310	72	2.372	162.160	72	2.405	119.650
73	2.451	153.670	73	2.465	152.040	73	2.407	164.650	73	2.440	121.760
74	2.486	155.930	74	2.500	154.670	74	2.442	167.110	74	2.475	123.950
75	2.520	157.990	75	2.535	157.200	75	2.476	169.270	75	2.510	126.480
76	2.556	160.290	76	2.571	159.700	76	2.511	171.190	76	2.543	129.180

77	2.590	162.330	77	2.605	162.060	77	2.546	173.110	77	2.580	132.020
78	2.626	164.360	78	2.640	164.390	78	2.581	174.720	78	2.613	134.850
79	2.661	166.200	79	2.675	165.600	79	2.617	176.000	79	2.649	137.710
						80	2.651	177.440	80	2.683	140.790
						81	2.686	178.600	81	2.719	143.740
						82	2.721	179.500	82	2.752	146.790
						83	2.756	180.420	83	2.787	149.870
									84	2.821	152.820
									85	2.857	155.980
									86	2.892	158.860
									87	2.926	161.730

APPENDIX C: PHASE 3 DATA

C-1. MWCNT, D = 30 +/-15nm, L = 1-5 micron

MWCNT-A (01)			MWCNT-A (02)			MWCNT-A (03)			MWCNT-A (04)			MWCNT-A (05)		
Point	Strain(%)	Stress(Mpa)	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress
1	0.000	-0.115	1	0.000	0.931	1	0.000	6.564	1	0.000	-0.125	1	0.000	0.141
2	0.000	-0.111	2	0.000	0.928	2	0.000	6.572	2	0.000	-0.121	2	0.000	0.145
3	0.000	-0.109	3	0.000	0.929	3	0.000	6.578	3	0.000	-0.124	3	0.000	0.153
4	0.015	0.108	4	0.004	1.047	4	0.006	6.783	4	0.006	-0.001	4	0.010	0.533
5	0.050	0.217	5	0.026	1.450	5	0.026	9.231	5	0.028	0.530	5	0.032	0.915
6	0.087	0.256	6	0.049	1.540	6	0.049	11.547	6	0.052	0.665	6	0.054	1.282
7	0.125	0.388	7	0.070	1.596	7	0.073	13.616	7	0.073	1.096	7	0.075	1.706
8	0.161	1.093	8	0.093	1.653	8	0.096	15.471	8	0.097	1.710	8	0.098	2.408
9	0.197	2.253	9	0.115	1.798	9	0.118	17.264	9	0.119	2.354	9	0.118	3.168
10	0.235	3.586	10	0.137	2.029	10	0.141	18.942	10	0.141	2.955	10	0.140	3.872
11	0.272	5.107	11	0.159	2.221	11	0.163	20.632	11	0.164	3.637	11	0.161	4.626
12	0.307	6.976	12	0.179	2.386	12	0.185	22.305	12	0.185	4.350	12	0.183	5.396
13	0.343	9.125	13	0.202	2.599	13	0.208	23.962	13	0.207	5.135	13	0.204	6.198
14	0.378	11.356	14	0.225	2.998	14	0.230	25.621	14	0.229	6.007	14	0.225	7.016
15	0.415	13.694	15	0.245	3.506	15	0.252	27.248	15	0.252	6.952	15	0.245	7.790
16	0.450	15.837	16	0.268	4.201	16	0.273	28.890	16	0.273	7.911	16	0.267	8.470
17	0.485	17.583	17	0.289	5.139	17	0.296	30.536	17	0.295	8.572	17	0.288	8.972
18	0.521	19.398	18	0.310	6.288	18	0.317	32.130	18	0.316	8.933	18	0.308	9.289
19	0.555	21.323	19	0.332	7.656	19	0.339	33.717	19	0.339	9.206	19	0.330	9.735
20	0.590	23.340	20	0.352	8.901	20	0.360	35.309	20	0.360	9.653	20	0.350	10.344
21	0.626	25.975	21	0.374	10.270	21	0.382	36.983	21	0.382	10.381	21	0.371	11.035
22	0.660	28.940	22	0.396	11.682	22	0.403	38.797	22	0.403	11.157	22	0.392	11.765
23	0.696	32.019	23	0.416	13.001	23	0.425	40.632	23	0.426	12.036	23	0.412	12.837
24	0.731	35.046	24	0.439	14.395	24	0.447	42.590	24	0.447	13.363	24	0.433	14.120
25	0.766	38.143	25	0.460	15.664	25	0.468	44.608	25	0.469	14.710	25	0.455	15.310
26	0.801	41.305	26	0.481	16.896	26	0.490	46.616	26	0.491	16.063	26	0.474	16.618
27	0.836	44.461	27	0.503	18.127	27	0.511	48.662	27	0.513	17.345	27	0.496	18.143
28	0.870	47.613	28	0.523	19.164	28	0.533	50.675	28	0.534	18.752	28	0.517	19.699
29	0.906	50.767	29	0.544	20.400	29	0.554	52.701	29	0.555	20.305	29	0.537	21.306
30	0.940	53.848	30	0.567	21.863	30	0.576	54.751	30	0.578	21.919	30	0.558	22.881
31	0.975	56.948	31	0.587	23.272	31	0.597	56.742	31	0.598	23.515	31	0.579	24.485
32	1.010	60.019	32	0.610	24.648	32	0.619	58.772	32	0.621	25.154	32	0.599	26.217
33	1.045	63.017	33	0.631	25.863	33	0.640	60.776	33	0.641	26.767	33	0.620	27.965
34	1.080	66.066	34	0.652	27.126	34	0.662	62.713	34	0.663	28.379	34	0.640	29.684
35	1.113	69.018	35	0.674	28.722	35	0.684	64.669	35	0.684	30.047	35	0.661	31.487
36	1.148	71.973	36	0.694	30.212	36	0.705	66.586	36	0.706	31.650	36	0.682	33.286
37	1.184	74.882	37	0.716	31.832	37	0.727	68.485	37	0.727	33.261	37	0.702	35.084
38	1.219	77.721	38	0.738	33.482	38	0.747	70.408	38	0.749	34.927	38	0.723	36.873
39	1.254	80.551	39	0.758	35.117	39	0.769	72.288	39	0.770	36.510	39	0.743	38.655
40	1.287	83.302	40	0.780	36.882	40	0.791	74.172	40	0.792	38.167	40	0.764	40.521
41	1.322	86.004	41	0.801	38.640	41	0.812	76.089	41	0.813	39.760	41	0.784	42.394
42	1.357	88.681	42	0.822	40.413	42	0.834	77.937	42	0.834	41.398	42	0.80499	44.171
43	1.392	91.230	43	0.844	42.266	43	0.855	79.839	43	0.857	43.015	43	0.82562	46.019
44	1.427	93.761	44	0.865	43.886	44	0.877	81.691	44	0.878	44.567	44	0.84618	47.877
45	1.462	96.235	45	0.886	45.585	45	0.897	83.510	45	0.900	46.118	45	0.86711	49.74
46	1.497	98.656	46	0.908	47.309	46	0.919	85.380	46	0.922	47.675	46	0.88757	51.648
47	1.532	101.070	47	0.928	48.892	47	0.941	87.249	47	0.943	49.178	47	0.90817	53.547
48	1.567	103.350	48	0.950	50.586	48	0.962	89.073	48	0.964	50.717	48	0.92889	55.518
49	1.601	105.610	49	0.971	52.205	49	0.984	90.936	49	0.986	52.241	49	0.94873	57.486
50	1.636	107.870	50	0.992	53.811	50	1.004	92.762	50	1.008	53.724	50	0.96942	59.44
51	1.671	109.990	51	1.015	55.495	51	1.026	94.606	51	1.029	55.215	51	0.99005	61.452
52	1.706	112.140	52	1.035	57.028	52	1.047	96.473	52	1.050	56.680	52	1.0107	63.475
53	1.741	114.220	53	1.056	58.644	53	1.069	98.288	53	1.072	58.153	53	1.0316	65.514
54	1.776	116.180	54	1.079	60.333	54	1.091	100.130	54	1.093	59.635	54	1.0521	67.559
55	1.811	118.200	55	1.099	61.882	55	1.112	101.990	55	1.115	61.071	55	1.0727	69.572
56	1.846	120.110	56	1.122	63.478	56	1.134	103.830	56	1.135	62.599	56	1.0926	71.633
57	1.881	121.980	57	1.143	65.082	57	1.155	105.670	57	1.157	64.111	57	1.1132	73.717
58	1.916	123.820	58	1.163	66.624	58	1.177	107.500	58	1.179	65.619	58	1.133	75.707
59	1.951	125.510	59	1.186	68.287	59	1.198	109.330	59	1.200	67.201	59	1.1537	77.837
60	1.986	127.190	60	1.207	69.825	60	1.220	111.160	60	1.222	68.751	60	1.1752	79.945
61	2.021	128.710	61	1.227	71.357	61	1.241	112.960	61	1.243	70.332	61	1.1951	81.97
62	2.056	130.260	62	1.250	73.015	62	1.262	114.780	62	1.265	71.927	62	1.2157	84.126
63	2.091	131.850	63	1.270	74.541	63	1.284	116.580	63	1.286	73.502	63	1.2363	86.269
64	2.126	133.260	64	1.293	76.169	64	1.305	118.370	64	1.308	75.053	64	1.2571	88.434
65	2.161	134.650	65	1.314	77.837	65	1.326	120.180	65	1.329	76.717	65	1.2777	90.597
66	2.196	135.920	66	1.335	79.455	66	1.347	121.980	66	1.351	78.354	66	1.2975	92.675
67	2.231	137.230	67	1.356	81.190	67	1.369	123.790	67	1.372	80.045	67	1.319	94.854
68	2.266	138.580	68	1.378	82.766	68	1.391	125.550	68	1.394	81.769	68	1.3397	96.976
69	2.301	139.870	69	1.398	84.366	69	1.412	127.300	69	1.416	83.459	69	1.3595	99.035
70	2.336	141.180	70	1.421	86.136	70	1.434	129.010	70	1.437	85.228	70	1.3802	101.16
71	2.371	142.520	71	1.441	87.793	71	1.454	130.730	71	1.459	86.967	71	1.4008	103.25

72	2.406	143.850	72	1.462	89.468	72	1.476	132.440	72	1.479	88.740	72	1.4215	105.32
73	2.441	145.460	73	1.485	91.255	73	1.497	134.200	73	1.501	90.548	73	1.4421	107.4
74	2.476	147.110	74	1.506	92.932	74	1.519	135.830	74	1.522	92.318	74	1.462	109.41
75	2.511	148.430	75	1.527	94.694	75	1.541	137.490	75	1.544	94.181	75	1.4833	111.49
			76	1.549	96.334				76	1.565	96.009	76	1.5041	113.51
			77	1.569	97.997				77	1.586	97.833	77	1.5242	115.46
			78	1.591	99.790				78	1.608	99.726	78	1.5447	117.41
			79	1.613	101.450				79	1.629	101.610	79	1.5644	119.34
			80	1.633	103.100				80	1.650	103.500	80	1.5851	121.27
			81	1.655	104.830				81	1.672	105.410	81	1.6059	123.11
			82	1.676	106.480				82	1.693	107.290	82	1.6256	124.84
			83	1.698	108.240				83	1.715	109.240	83	1.6471	126.66
			84	1.718	109.910				84	1.735	111.140	84	1.6678	128.41
			85	1.739	111.520				85	1.757	113.060	85	1.6877	130.04
			86	1.761	113.260				86	1.778	115.000	86	1.7083	131.73
			87	1.782	114.900				87	1.800	116.890	87	1.7296	133.28
			88	1.803	116.530				88	1.822	118.740	88	1.7503	134.64
			89	1.824	118.240				89	1.843	120.650	89	1.7712	136.01
			90	1.845	119.880				90	1.865	122.490	90	1.7909	137.32
			91	1.867	121.630				91	1.886	124.400	91	1.8124	138.7
			92	1.887	123.250				92	1.908	126.270	92	1.8331	140.02
			93	1.908	124.880				93	1.929	128.060	93	1.8531	141.19
			94	1.931	126.730				94	1.951	129.910	94	1.8736	142.19
			95	1.951	128.420				95	1.972	131.700	95	1.8949	142.93
			96	1.973	130.090				96	1.994	133.510			
			97	1.995	131.890				97	2.016	135.290			
			98	2.015	133.540				98	2.036	137.000			
			99	2.038	135.240				99	2.058	138.670			
			100	2.058	136.930				100	2.079	140.100			
			101	2.079	138.560									
			102	2.101	140.370									
			103	2.122	142.070									
			104	2.143	143.720									
			105	2.164	145.470									
			106	2.186	147.040									
			107	2.207	148.630									
			108	2.228	150.010									

C-2. MWCNT, D = 25 +/-5nm, L = 10-30 microns

MWCNT-B (01)			MWCNT-B (02)			MWCNT-B (03)			MWCNT-B (04)			MWCNT-B (05)		
Point	Strain(%)	Stress(Mpa)	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress
1	0.000	0.109	1	0.000	1.608	1	0.000	-0.062	1	0.000	0.703	1	0.000	0.124
2	0.000	0.109	2	0.000	1.621	2	0.000	-0.072	2	0.000	0.691	2	0.000	0.109
3	0.000	0.103	3	0.000	1.621	3	0.000	-0.073	3	0.000	0.698	3	0.000	0.118
4	0.015	0.127	4	0.009	1.628	4	0.006	0.016	4	0.005	0.882	4	0.004	0.164
5	0.052	0.130	5	0.033	1.620	5	0.027	0.099	5	0.026	1.642	5	0.023	0.832
6	0.089	0.170	6	0.054	1.620	6	0.050	0.196	6	0.048	2.448	6	0.046	1.345
7	0.126	0.631	7	0.076	1.940	7	0.073	0.339	7	0.072	3.268	7	0.067	1.770
8	0.164	1.540	8	0.098	2.746	8	0.096	0.505	8	0.094	4.051	8	0.089	2.259
9	0.199	2.702	9	0.121	3.565	9	0.118	0.870	9	0.116	4.827	9	0.111	2.899
10	0.236	4.021	10	0.143	4.417	10	0.142	1.386	10	0.139	5.673	10	0.132	3.493
11	0.273	5.460	11	0.163	5.268	11	0.164	1.978	11	0.160	6.493	11	0.154	4.320
12	0.309	7.097	12	0.187	6.149	12	0.185	2.590	12	0.183	7.421	12	0.176	5.196
13	0.346	8.915	13	0.208	7.191	13	0.208	3.216	13	0.204	8.509	13	0.197	6.057
14	0.380	10.663	14	0.229	8.356	14	0.229	3.881	14	0.227	9.648	14	0.218	6.907
15	0.417	12.456	15	0.251	9.598	15	0.252	4.583	15	0.248	10.852	15	0.239	7.721
16	0.452	14.527	16	0.273	10.856	16	0.273	5.351	16	0.271	12.190	16	0.261	8.578
17	0.487	16.522	17	0.294	12.250	17	0.295	6.239	17	0.292	13.654	17	0.282	9.440
18	0.523	18.313	18	0.315	13.581	18	0.316	7.225	18	0.315	15.198	18	0.302	10.286
19	0.558	20.798	19	0.337	14.788	19	0.338	8.248	19	0.336	16.731	19	0.323	11.217
20	0.593	23.418	20	0.358	15.886	20	0.360	9.380	20	0.358	18.341	20	0.345	12.304
21	0.630	26.211	21	0.380	16.865	21	0.381	10.572	21	0.379	19.947	21	0.366	13.483
22	0.664	29.013	22	0.402	17.882	22	0.403	11.839	22	0.401	21.586	22	0.387	14.735
23	0.699	31.799	23	0.423	18.930	23	0.425	13.193	23	0.422	23.251	23	0.407	15.977
24	0.734	34.626	24	0.443	20.181	24	0.447	14.564	24	0.444	24.938	24	0.429	17.372
25	0.770	37.361	25	0.466	21.781	25	0.468	15.925	25	0.466	26.653	25	0.450	18.740
26	0.805	40.089	26	0.486	23.390	26	0.490	17.308	26	0.488	28.400	26	0.470	20.119
27	0.840	42.776	27	0.507	24.958	27	0.512	18.671	27	0.509	30.143	27	0.492	21.587
28	0.876	45.409	28	0.529	26.591	28	0.533	20.034	28	0.530	31.978	28	0.513	23.045
29	0.911	48.052	29	0.550	28.183	29	0.554	21.430	29	0.552	33.844	29	0.533	24.530
30	0.945	50.618	30	0.571	29.754	30	0.576	22.869	30	0.573	35.726	30	0.554	26.095
31	0.980	53.172	31	0.593	31.358	31	0.597	24.338	31	0.595	37.674	31	0.575	27.549
32	1.016	55.757	32	0.614	32.881	32	0.619	25.893	32	0.616	39.584	32	0.596	29.121
33	1.051	58.281	33	0.635	34.456	33	0.640	27.424	33	0.638	41.608	33	0.617	30.658
34	1.086	60.844	34	0.656	35.992	34	0.662	28.958	34	0.659	43.614	34	0.637	32.109
35	1.122	63.419	35	0.677	37.457	35	0.684	30.444	35	0.680	45.572	35	0.658	33.651
36	1.157	66.008	36	0.698	38.988	36	0.705	31.913	36	0.703	47.672	36	0.678	35.182
37	1.192	68.679	37	0.720	40.546	37	0.727	33.335	37	0.724	49.720	37	0.699	36.750
38	1.226	71.267	38	0.742	42.008	38	0.748	34.769	38	0.746	51.751	38	0.720	38.409
39	1.261	73.874	39	0.763	43.516	39	0.770	36.191	39	0.767	53.854	39	0.741	40.022
40	1.297	76.524	40	0.785	44.953	40	0.791	37.588	40	0.788	55.903	40	0.762	41.761
41	1.332	79.052	41	0.806	46.454	41	0.813	38.986	41	0.809	58.018	41	0.782	43.500
42	1.367	81.643	42	0.827	47.922	42	0.834	40.377	42	0.832	60.126	42	0.80337	45.154
43	1.403	84.215	43	0.848	49.318	43	0.856	41.779	43	0.853	62.202	43	0.82413	46.931
44	1.436	86.657	44	0.869	50.753	44	0.878	43.199	44	0.874	64.333	44	0.84493	48.683
45	1.472	89.209	45	0.891	52.229	45	0.900	44.607	45	0.896	66.479	45	0.866	50.453
46	1.507	91.610	46	0.912	53.637	46	0.922	45.988	46	0.917	68.616	46	0.88583	52.172
47	1.542	94.073	47	0.933	55.104	47	0.943	47.397	47	0.939	70.779	47	0.9066	53.903
48	1.579	96.540	48	0.955	56.506	48	0.965	48.819	48	0.959	72.921	48	0.92743	55.747
49	1.613	98.899	49	0.977	57.977	49	0.986	50.229	49	0.981	75.105	49	0.9483	57.563
50	1.648	101.340	50	0.997	59.372	50	1.008	51.607	50	1.003	77.295	50	0.9684	59.335
51	1.685	103.810	51	1.019	60.743	51	1.028	53.002	51	1.023	79.424	51	0.98993	61.224
52	1.719	106.310	52	1.040	62.190	52	1.050	54.402	52	1.045	81.636	52	1.01	63.067
53	1.756	108.880	53	1.062	63.594	53	1.072	55.808	53	1.066	83.846	53	1.031	64.947
54	1.791	111.320	54	1.082	65.010	54	1.093	57.227	54	1.087	86.016	54	1.0516	66.824
55	1.825	113.720	55	1.104	66.458	55	1.115	58.647	55	1.109	88.226	55	1.0725	68.648
56	1.860	116.020	56	1.125	67.863	56	1.136	60.060	56	1.130	90.384	56	1.0933	70.618
57	1.896	118.320	57	1.146	69.306	57	1.157	61.498	57	1.152	92.598	57	1.1141	72.499
58	1.931	120.630	58	1.168	70.729	58	1.178	62.960	58	1.173	94.781	58	1.1342	74.348
59	1.966	123.000	59	1.188	72.175	59	1.200	64.426	59	1.194	96.937	59	1.155	76.312
60	2.001	125.410	60	1.210	73.665	60	1.222	65.904	60	1.216	99.108	60	1.1766	78.209
61	2.037	127.800	61	1.232	75.150	61	1.243	67.429	61	1.237	101.290	61	1.1967	80.14
62	2.072	130.000	62	1.253	76.603	62	1.265	68.926	62	1.259	103.350	62	1.2183	82.071
63	2.107	132.270	63	1.274	78.086	63	1.286	70.503	63	1.280	105.500	63	1.2383	83.962
64	2.143	134.420	64	1.296	79.586	64	1.308	72.080	64	1.302	107.570	64	1.2592	85.978
			65	1.318	81.095	65	1.329	73.652	65	1.323	109.670	65	1.28	87.903
			66	1.339	82.622	66	1.351	75.229	66	1.345	111.790	66	1.3	89.74
			67	1.360	84.055	67	1.372	76.744	67	1.366	113.850	67	1.3217	91.687
			68	1.382	85.549	68	1.394	78.295	68	1.388	115.910	68	1.3425	93.54
			69	1.403	87.043	69	1.416	79.878	69	1.410	117.980	69	1.3625	95.343
			70	1.425	88.494	70	1.436	81.470	70	1.431	119.970	70	1.3833	97.208
			71	1.446	89.971	71	1.458	83.071	71	1.453	122.010	71	1.4042	98.953
			72	1.468	91.417	72	1.479	84.694	72	1.474	123.980	72	1.425	100.73
			73	1.489	92.869	73	1.501	86.336	73	1.496	125.960	73	1.445	102.47
			74	1.510	94.266	74	1.522	88.002	74	1.517	127.930	74	1.4657	104.1
			75	1.531	95.608	75	1.544	89.658	75	1.538	129.830	75	1.4868	105.85
			76	1.552	97.025	76	1.566	91.290	76	1.560	131.790	76	1.5075	107.45

			77	1.574	98.428	77	1.586	92.927	77	1.582	133.790	77	1.5277	109.03
			78	1.595	99.748	78	1.608	94.608	78	1.603	135.650	78	1.5483	110.68
			79	1.616	101.110	79	1.629	96.250	79	1.625	137.510	79	1.569	112.25
			80	1.638	102.430	80	1.651	97.924	80	1.647	139.320	80	1.59	113.87
			81	1.660	103.790	81	1.672	99.604	81	1.668	141.130	81	1.6108	115.4
			82	1.681	105.070	82	1.694	101.290	82	1.689	142.900	82	1.6316	116.94
			83	1.702	106.290	83	1.716	103.010	83	1.710	144.590	83	1.6526	118.48
			84	1.723	107.580	84	1.737	104.720	84	1.732	146.170	84	1.6734	119.97
			85	1.745	108.880	85	1.759	106.460	85	1.754	147.820	85	1.6943	121.43
			86	1.766	110.080	86	1.779	108.180	86	1.775	149.440	86	1.715	122.88
			87	1.787	111.330	87	1.801	109.920	87	1.797	151.060	87	1.7357	124.31
			88	1.809	112.500	88	1.823	111.680	88	1.818	152.630	88	1.7566	125.79
			89	1.830	113.700	89	1.844	113.390	89	1.840	154.240	89	1.7775	127.19
			90	1.851	114.960	90	1.866	115.090	90	1.861	155.760	90	1.7983	128.5
			91	1.872	116.180	91	1.887	116.830	91	1.883	157.210	91	1.8192	129.93
			92	1.893	117.390	92	1.909	118.580	92	1.904	158.580	92	1.84	131.3
			93	1.915	118.620	93	1.930	120.360	93	1.926	159.960	93	1.861	132.64
			94	1.936	119.830	94	1.951	122.070	94	1.947	161.160	94	1.8826	134
			95	1.957	121.110	95	1.972	123.790	95	1.969	161.770	95	1.9024	135.27
			96	1.978	122.400	96	1.994	125.510				96	1.9234	136.53
			97	1.999	123.720	97	2.015	127.210				97	1.9442	137.79
			98	2.020	125.090	98	2.036	128.960				98	1.965	138.99
			99	2.042	126.430	99	2.058	130.670				99	1.9858	140.21
			100	2.063	127.890	100	2.079	132.340				100	2.0067	141.33
			101	2.085	129.320	101	2.101	133.980				101	2.0276	142.49
			102	2.106	130.690	102	2.122	135.440				102	2.0491	143.61
			103	2.128	132.110							103	2.0699	144.7
			104	2.149	133.480							104	2.0908	145.8
			105	2.170	134.880							105	2.1117	146.78
			106	2.192	136.250							106	2.1325	147.79
			107	2.213	137.540							107	2.1533	148.82
			108	2.233	138.840							108	2.1741	149.75
			109	2.256	140.140							109	2.1951	150.64
			110	2.276	141.270							110	2.2158	151.5
			111	2.298	142.350							111	2.2366	152.37
												112	2.2582	153.23
												113	2.2783	153.49

C-3. MWCNT, D = 15 +/-5nm, L = 5-20 micron

MWCNT-C (01)			MWCNT-C (02)			MWCNT-C (03)			MWCNT-C (04)			MWCNT-C (05)		
Point	Strain(%)	Stress(Mpa)	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress
1	0.000	0.242	1	0.000	1.475	1	0.000	0.031	1	0.000	0.158	1	0.000	0.748
2	0.000	0.238	2	0.000	1.481	2	0.000	0.029	2	0.000	0.157	2	0.000	0.746
3	0.000	0.234	3	0.000	1.470	3	0.000	0.027	3	0.000	0.153	3	0.000	0.751
4	0.011	0.522	4	0.007	1.627	4	0.006	0.130	4	0.009	0.338	4	0.004	0.786
5	0.047	1.943	5	0.028	1.804	5	0.027	0.165	5	0.030	0.517	5	0.024	1.699
6	0.083	3.577	6	0.051	2.118	6	0.049	0.247	6	0.054	0.872	6	0.046	2.527
7	0.120	5.152	7	0.074	2.610	7	0.072	0.342	7	0.077	1.575	7	0.068	3.459
8	0.157	6.726	8	0.095	3.302	8	0.095	0.467	8	0.100	2.390	8	0.089	4.393
9	0.195	8.438	9	0.118	4.225	9	0.117	0.888	9	0.122	3.236	9	0.111	5.278
10	0.230	10.086	10	0.139	5.072	10	0.140	1.520	10	0.145	4.129	10	0.133	6.293
11	0.266	11.836	11	0.161	5.904	11	0.162	2.130	11	0.167	5.134	11	0.154	7.304
12	0.302	13.810	12	0.184	6.856	12	0.185	2.767	12	0.190	6.168	12	0.175	8.260
13	0.338	15.925	13	0.205	7.865	13	0.207	3.382	13	0.211	7.276	13	0.197	9.260
14	0.373	18.299	14	0.227	9.018	14	0.228	4.044	14	0.234	8.409	14	0.218	10.252
15	0.410	20.843	15	0.249	10.223	15	0.250	4.746	15	0.256	9.518	15	0.239	11.420
16	0.445	23.385	16	0.270	11.434	16	0.272	5.478	16	0.278	10.550	16	0.261	12.657
17	0.480	26.087	17	0.291	12.725	17	0.294	6.242	17	0.300	11.426	17	0.281	13.870
18	0.517	28.967	18	0.313	13.916	18	0.315	6.963	18	0.322	12.288	18	0.303	15.230
19	0.551	31.760	19	0.334	14.964	19	0.338	7.593	19	0.344	13.186	19	0.324	16.679
20	0.586	34.648	20	0.356	15.993	20	0.359	8.001	20	0.365	14.085	20	0.344	18.199
21	0.622	37.468	21	0.377	16.997	21	0.381	8.390	21	0.387	14.916	21	0.366	19.837
22	0.657	40.252	22	0.398	18.262	22	0.403	8.971	22	0.409	15.829	22	0.386	21.390
23	0.692	43.099	23	0.421	19.588	23	0.423	9.658	23	0.430	17.126	23	0.407	22.970
24	0.727	45.752	24	0.441	20.692	24	0.445	10.672	24	0.452	18.540	24	0.429	24.566
25	0.763	48.403	25	0.462	21.790	25	0.466	11.849	25	0.474	20.006	25	0.449	26.033
26	0.798	51.038	26	0.484	23.159	26	0.488	13.093	26	0.495	21.504	26	0.471	27.591
27	0.832	53.508	27	0.505	24.644	27	0.510	14.375	27	0.517	23.036	27	0.492	29.073
28	0.869	56.105	28	0.526	26.245	28	0.531	15.667	28	0.539	24.574	28	0.512	30.511
29	0.904	58.647	29	0.548	27.869	29	0.553	16.963	29	0.560	26.151	29	0.533	32.016
30	0.938	61.216	30	0.569	29.514	30	0.574	18.406	30	0.582	27.712	30	0.554	33.425
31	0.975	63.870	31	0.591	31.171	31	0.596	19.915	31	0.603	29.295	31	0.574	34.808
32	1.010	66.441	32	0.611	32.760	32	0.618	21.491	32	0.624	30.907	32	0.596	36.277
33	1.044	69.013	33	0.633	34.446	33	0.640	23.098	33	0.647	32.540	33	0.616	37.631
34	1.079	71.608	34	0.655	36.075	34	0.661	24.706	34	0.668	34.163	34	0.638	39.038
35	1.114	74.054	35	0.675	37.637	35	0.682	26.374	35	0.690	35.783	35	0.658	40.429
36	1.150	76.605	36	0.697	39.241	36	0.703	28.057	36	0.712	37.421	36	0.678	41.752
37	1.184	79.128	37	0.718	40.763	37	0.725	29.727	37	0.732	39.075	37	0.699	43.127
38	1.219	81.642	38	0.738	42.315	38	0.747	31.417	38	0.754	40.763	38	0.720	44.503
39	1.256	84.232	39	0.761	43.848	39	0.768	33.063	39	0.776	42.411	39	0.741	45.867
40	1.291	86.721	40	0.781	45.320	40	0.790	34.719	40	0.797	44.078	40	0.762	47.211
41	1.326	89.268	41	0.803	46.830	41	0.811	36.383	41	0.819	45.753	41	0.782	48.503
42	1.362	91.818	42	0.824	48.301	42	0.833	37.984	42	0.841	47.447	42	0.80253	49.844
43	1.396	94.256	43	0.845	49.707	43	0.854	39.595	43	0.862	49.125	43	0.8242	51.248
44	1.432	96.795	44	0.867	51.198	44	0.876	41.164	44	0.883	50.823	44	0.84423	52.54
45	1.468	99.293	45	0.887	52.596	45	0.897	42.736	45	0.905	52.543	45	0.866	53.891
46	1.503	101.790	46	0.909	54.016	46	0.919	44.285	46	0.926	54.315	46	0.88653	55.213
47	1.538	104.360	47	0.930	55.436	47	0.941	45.787	47	0.948	56.097	47	0.90657	56.505
48	1.573	106.780	48	0.951	56.791	48	0.962	47.314	48	0.969	57.870	48	0.9284	57.894
49	1.607	109.260	49	0.973	58.183	49	0.984	48.832	49	0.990	59.649	49	0.9483	59.174
50	1.643	111.740	50	0.994	59.556	50	1.005	50.343	50	1.012	61.447	50	0.9692	60.527
51	1.678	114.120	51	1.015	60.893	51	1.027	51.894	51	1.034	63.269	51	0.98997	61.883
52	1.713	116.630	52	1.037	62.287	52	1.049	53.419	52	1.055	65.057	52	1.0109	63.206
53	1.749	119.100	53	1.058	63.609	53	1.070	54.905	53	1.076	66.857	53	1.0309	64.523
54	1.784	121.510	54	1.080	64.899	54	1.092	56.445	54	1.098	68.676	54	1.0524	65.892
55	1.821	123.970	55	1.101	66.199	55	1.113	57.964	55	1.120	70.484	55	1.0725	67.17
56	1.855	126.300	56	1.122	67.415	56	1.135	59.500	56	1.140	72.290	56	1.0934	68.494
57	1.891	128.760	57	1.143	68.691	57	1.156	61.019	57	1.162	74.106	57	1.1142	69.766
58	1.927	131.140	58	1.165	69.957	58	1.178	62.498	58	1.184	75.934	58	1.1342	71.048
59	1.961	133.420	59	1.186	71.133	59	1.199	64.046	59	1.205	77.738	59	1.1558	72.386
60	1.996	135.680	60	1.208	72.459	60	1.221	65.592	60	1.227	79.517	60	1.1758	73.647
61	2.031	137.710	61	1.228	73.631	61	1.242	67.116	61	1.248	81.315	61	1.1967	74.955
62	2.066	139.620	62	1.250	74.860	62	1.264	68.660	62	1.270	83.118	62	1.2183	76.284
63	2.102	141.600	63	1.271	76.031	63	1.285	70.167	63	1.292	84.937	63	1.2383	77.53
64	2.137	142.910	64	1.291	77.140	64	1.306	71.682	64	1.314	86.763	64	1.26	78.794
			65	1.313	78.329	65	1.328	73.226	65	1.335	88.581	65	1.28	80.007
			66	1.334	79.481	66	1.349	74.718	66	1.357	90.381	66	1.3009	81.258
			67	1.356	80.565	67	1.371	76.234	67	1.378	92.234	67	1.3217	82.54
			68	1.377	81.720	68	1.392	77.744	68	1.400	94.054	68	1.3425	83.74
			69	1.398	82.794	69	1.413	79.208	69	1.422	95.861	69	1.3625	84.961
			70	1.420	83.884	70	1.435	80.754	70	1.443	97.642	70	1.3841	86.233
			71	1.441	84.972	71	1.457	82.241	71	1.465	99.420	71	1.4042	87.425
			72	1.462	85.930	72	1.478	83.750	72	1.486	101.160	72	1.425	88.667
			73	1.485	86.926	73	1.500	85.237	73	1.508	102.950	73	1.4458	89.839
			74	1.506	87.867	74	1.522	86.665	74	1.530	104.740	74	1.4667	91.021
			75	1.527	88.703	75	1.543	88.140	75	1.552	106.560	75	1.4875	92.283
			76	1.549	89.625	76	1.565	89.595	76	1.573	108.280	76	1.5075	93.417

			77	1.570	90.513	77	1.585	91.047	77	1.595	110.020	77	1.5285	94.64
			78	1.592	91.337	78	1.607	92.488	78	1.617	111.780	78	1.549	95.869
			79	1.613	92.201	79	1.629	93.903	79	1.638	113.490	79	1.5692	96.96
			80	1.634	92.925	80	1.650	95.326	80	1.659	115.230	80	1.5901	98.152
			81	1.656	93.728	81	1.672	96.750	81	1.681	116.950	81	1.6108	99.313
			82	1.677	94.489	82	1.693	98.113	82	1.702	118.630	82	1.6317	100.47
			83	1.698	95.211	83	1.714	99.482	83	1.724	120.320	83	1.6533	101.75
			84	1.720	96.032	84	1.735	100.840	84	1.746	121.960	84	1.6734	102.92
			85	1.741	96.817	85	1.757	102.170	85	1.767	123.540	85	1.6941	104.13
			86	1.762	97.599	86	1.779	103.460	86	1.789	125.100	86	1.7158	105.38
			87	1.784	98.396	87	1.800	104.750	87	1.810	126.470	87	1.7359	106.56
			88	1.805	99.065	88	1.822	106.050				88	1.7567	107.7
			89	1.827	99.770	89	1.843	107.340				89	1.7774	108.82
			90	1.848	100.480	90	1.864	108.580				90	1.7982	109.94
			91	1.869	101.050	91	1.886	109.840				91	1.8191	111.08
			92	1.892	101.800	92	1.908	111.050				92	1.84	112.14
			93	1.912	102.450	93	1.928	112.120				93	1.8609	113.22
			94	1.933	103.140	94	1.950	113.340				94	1.8817	114.33
			95	1.956	103.830	95	1.972	114.520				95	1.9025	115.36
			96	1.976	104.340	96	1.993	115.690				96	1.9234	116.37
			97	1.998	104.950	97	2.015	116.830				97	1.9441	117.43
			98	2.019	105.610	98	2.036	117.940				98	1.9649	118.5
			99	2.040	106.230	99	2.058	119.000				99	1.9858	119.63
			100	2.062	107.060	100	2.079	120.030				100	2.0067	120.68
			101	2.083	107.910	101	2.100	120.910				101	2.0275	121.73
			102	2.104	108.810	102	2.122	121.910				102	2.0492	122.78
			103	2.125	109.750	103	2.143	122.900				103	2.0692	123.86
			104	2.146	110.670	104	2.165	123.870				104	2.0909	124.86
			105	2.168	111.720	105	2.186	124.870				105	2.1115	125.79
			106	2.188	112.720	106	2.208	125.820				106	2.1324	126.7
			107	2.209	113.680	107	2.229	126.810				107	2.1533	127.51
			108	2.231	114.680	108	2.250	127.800				108	2.1742	128.24
			109	2.252	115.630	109	2.272	128.730				109	2.195	129.02
			110	2.274	116.590	110	2.293	129.730				110	2.2158	129.77
			111	2.295	117.630	111	2.315	130.670				111	2.2368	130.56
			112	2.316	118.580	112	2.336	131.450				112	2.2576	131.3
			113	2.338	119.610							113	2.2783	132.02
			114	2.359	120.640							114	2.2999	132.83
			115	2.380	121.640							115	2.3208	133.6
			116	2.402	122.710							116	2.3409	134.32
			117	2.423	123.750							117	2.3625	135.16
			118	2.444	124.790							118	2.3824	135.95
			119	2.466	125.860							119	2.4035	136.85
			120	2.486	126.800							120	2.4241	137.72
			121	2.508	127.820							121	2.445	138.58
			122	2.529	128.850							122	2.4666	139.47
			123	2.551	129.820							123	2.4866	140.33
			124	2.572	130.870							124	2.5076	141.09
			125	2.593	131.890							125	2.5292	141.86
			126	2.614	132.810							126	2.55	142.43
			127	2.635	133.140									

C-4. MWCNT, D = 30 +/-15nm, L = 5-20 micron

MWCNT-D (01)			MWCNT-D (02)			MWCNT-D (03)			MWCNT-D (04)			MWCNT-F (05)		
Point	Strain(%)	Stress(Mpa)	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress
1	0.000	-0.015	1	0.000	1.768	1	0.000	-0.006	1	0.000	0.054	1	0.000	0.094
2	0.000	-0.017	2	0.000	1.770	2	0.000	-0.001	2	0.000	0.050	2	0.000	0.076
3	0.000	-0.011	3	0.000	1.770	3	0.000	-0.002	3	0.000	0.056	3	0.000	0.093
4	0.015	0.104	4	0.004	1.899	4	0.009	0.122	4	0.005	0.116	4	0.007	0.322
5	0.052	0.195	5	0.026	2.712	5	0.026	0.109	5	0.026	0.115	5	0.028	0.832
6	0.088	0.401	6	0.047	3.565	6	0.049	0.108	6	0.050	0.112	6	0.050	1.109
7	0.125	1.483	7	0.069	4.377	7	0.073	0.127	7	0.072	0.132	7	0.071	1.414
8	0.161	2.845	8	0.093	5.262	8	0.095	0.193	8	0.095	0.226	8	0.094	1.938
9	0.197	4.404	9	0.114	6.183	9	0.117	0.382	9	0.117	0.443	9	0.115	2.668
10	0.234	6.011	10	0.137	7.198	10	0.140	0.812	10	0.140	0.917	10	0.137	3.445
11	0.270	7.716	11	0.159	8.228	11	0.162	1.372	11	0.162	1.483	11	0.158	4.212
12	0.307	9.619	12	0.179	9.344	12	0.184	1.955	12	0.185	1.976	12	0.179	4.982
13	0.342	11.391	13	0.202	10.674	13	0.206	2.491	13	0.206	2.447	13	0.201	5.783
14	0.377	13.071	14	0.223	11.987	14	0.228	3.005	14	0.228	2.983	14	0.223	6.542
15	0.413	14.545	15	0.246	13.321	15	0.250	3.574	15	0.250	3.477	15	0.244	7.233
16	0.448	15.932	16	0.267	14.725	16	0.272	4.224	16	0.272	4.041	16	0.265	7.954
17	0.483	17.201	17	0.288	16.079	17	0.294	4.865	17	0.293	4.742	17	0.285	8.872
18	0.518	17.974	18	0.310	17.548	18	0.316	5.689	18	0.315	5.450	18	0.307	9.775
19	0.553	19.268	19	0.332	19.030	19	0.338	6.623	19	0.337	6.079	19	0.328	10.682
20	0.590	21.060	20	0.353	20.516	20	0.360	7.563	20	0.359	6.484	20	0.348	11.704
21	0.625	22.820	21	0.375	22.116	21	0.381	8.478	21	0.380	6.754	21	0.369	12.877
22	0.660	24.541	22	0.396	23.681	22	0.403	9.354	22	0.403	7.253	22	0.390	13.932
23	0.693	26.322	23	0.417	25.291	23	0.424	10.184	23	0.423	7.930	23	0.410	15.250
24	0.730	28.678	24	0.439	26.896	24	0.446	11.069	24	0.446	8.670	24	0.432	16.647
25	0.765	31.413	25	0.460	28.441	25	0.467	11.994	25	0.466	9.592	25	0.452	18.086
26	0.798	34.122	26	0.481	30.069	26	0.489	12.942	26	0.488	10.701	26	0.473	19.603
27	0.833	36.894	27	0.503	31.626	27	0.510	14.386	27	0.509	11.892	27	0.494	21.203
28	0.868	39.676	28	0.524	33.124	28	0.532	16.026	28	0.532	13.045	28	0.514	22.810
29	0.903	42.450	29	0.545	34.716	29	0.553	17.699	29	0.553	14.135	29	0.535	24.535
30	0.937	45.257	30	0.567	36.207	30	0.575	19.433	30	0.575	15.229	30	0.557	26.267
31	0.972	48.085	31	0.588	37.742	31	0.597	21.131	31	0.596	16.266	31	0.577	27.955
32	1.007	50.930	32	0.609	39.301	32	0.618	22.863	32	0.618	17.413	32	0.598	29.663
33	1.042	53.789	33	0.630	40.816	33	0.640	24.607	33	0.640	18.716	33	0.619	31.321
34	1.077	56.582	34	0.651	42.386	34	0.661	26.343	34	0.661	19.963	34	0.640	32.999
35	1.112	59.402	35	0.673	43.916	35	0.684	28.100	35	0.683	21.220	35	0.661	34.684
36	1.147	62.210	36	0.694	45.373	36	0.705	29.837	36	0.704	22.473	36	0.681	36.327
37	1.182	64.912	37	0.715	46.953	37	0.727	31.508	37	0.726	23.641	37	0.702	38.003
38	1.217	67.609	38	0.738	48.465	38	0.748	33.190	38	0.747	24.875	38	0.723	39.669
39	1.251	70.298	39	0.759	49.927	39	0.770	34.871	39	0.769	26.101	39	0.743	41.316
40	1.286	72.987	40	0.780	51.458	40	0.791	36.494	40	0.791	27.345	40	0.763	42.972
41	1.321	75.612	41	0.802	52.875	41	0.813	38.112	41	0.812	28.582	41	0.784	44.634
42	1.356	78.205	42	0.823	54.406	42	0.834	39.687	42	0.833	29.789	42	0.805	46.265
43	1.391	80.756	43	0.845	55.893	43	0.856	41.298	43	0.855	31.090	43	0.82583	47.853
44	1.426	83.333	44	0.866	57.278	44	0.878	42.859	44	0.877	32.341	44	0.84583	49.405
45	1.461	85.809	45	0.887	58.793	45	0.898	44.435	45	0.897	33.569	45	0.86667	50.975
46	1.496	88.258	46	0.909	60.227	46	0.920	46.052	46	0.919	34.879	46	0.8875	52.538
47	1.529	90.663	47	0.930	61.591	47	0.941	47.622	47	0.941	36.124	47	0.90833	54.069
48	1.566	93.081	48	0.951	63.062	48	0.963	49.201	48	0.962	37.432	48	0.92917	55.655
49	1.601	95.418	49	0.973	64.447	49	0.985	50.764	49	0.984	38.730	49	0.9498	57.254
50	1.635	97.673	50	0.994	65.900	50	1.006	52.363	50	1.005	39.962	50	0.97083	58.91
51	1.669	99.948	51	1.016	67.296	51	1.028	53.920	51	1.028	41.261	51	0.99167	60.534
52	1.706	102.180	52	1.036	68.634	52	1.048	55.499	52	1.049	42.494	52	1.0123	62.203
53	1.741	104.350	53	1.058	70.120	53	1.070	57.079	53	1.070	43.683	53	1.0333	63.985
54	1.776	106.300	54	1.080	71.524	54	1.091	58.655	54	1.091	44.945	54	1.0542	65.811
55	1.810	108.290	55	1.101	72.894	55	1.113	60.254	55	1.114	46.209	55	1.075	67.573
56	1.845	110.330	56	1.122	74.394	56	1.135	61.836	56	1.135	47.426	56	1.0958	69.478
57	1.881	112.320	57	1.144	75.824	57	1.156	63.404	57	1.156	48.729	57	1.1157	71.34
58	1.915	114.190	58	1.165	77.373	58	1.178	64.978	58	1.178	49.991	58	1.1366	73.263
59	1.950	116.110	59	1.187	78.839	59	1.200	66.515	59	1.199	51.311	59	1.1575	75.222
60	1.986	117.900	60	1.208	80.244	60	1.221	68.059	60	1.221	52.592	60	1.1782	77.134
61	2.021	119.630	61	1.230	81.803	61	1.242	69.615	61	1.242	53.811	61	1.1992	79.112
62	2.055	121.350	62	1.250	83.266	62	1.264	71.174	62	1.264	55.119	62	1.2201	81.154
63	2.090	123.010	63	1.272	84.681	63	1.285	72.719	63	1.285	56.425	63	1.2409	83.103
64	2.126	124.670	64	1.293	86.173	64	1.307	74.258	64	1.306	57.673	64	1.2618	85.159
65	2.161	126.350	65	1.315	87.606	65	1.329	75.823	65	1.328	59.011	65	1.2824	87.172
66	2.195	128.020	66	1.336	89.150	66	1.350	77.363	66	1.349	60.323	66	1.3034	89.182
67	2.230	129.770	67	1.357	90.646	67	1.372	78.903	67	1.371	61.666	67	1.324	91.166
68	2.266	131.560	68	1.378	92.126	68	1.392	80.399	68	1.392	62.984	68	1.3449	93.158
69	2.301	133.420	69	1.399	93.714	69	1.414	81.912	69	1.414	64.268	69	1.3657	95.164
70	2.335	135.220	70	1.421	95.195	70	1.435	83.470	70	1.435	65.632	70	1.3866	97.165
71	2.370	137.070	71	1.442	96.748	71	1.457	84.947	71	1.457	66.985	71	1.4076	99.124
72	2.405	138.910	72	1.463	98.380	72	1.478	86.481	72	1.478	68.293	72	1.4284	101.13
73	2.440	140.710	73	1.484	99.938	73	1.500	88.010	73	1.500	69.671	73	1.4491	103.07
74	2.475	142.500	74	1.505	101.600	74	1.522	89.565	74	1.522	70.992	74	1.47	105.01

75	2.510	144.300	75	1.527	103.190	75	1.543	91.134	75	1.543	72.365	75	1.4908	106.89
76	2.544	146.000	76	1.547	104.790	76	1.565	92.655	76	1.565	73.699	76	1.5116	108.7
77	2.580	147.750	77	1.568	106.540	77	1.586	94.220	77	1.586	75.048	77	1.5325	110.49
78	2.613	149.410	78	1.591	108.230	78	1.608	95.773	78	1.607	76.443	78	1.5532	112.24
79	2.649	150.960	79	1.612	109.890	79	1.629	97.334	79	1.628	77.817	79	1.5742	113.94
80	2.684	152.460	80	1.633	111.570	80	1.651	98.892	80	1.650	79.170	80	1.595	115.67
81	2.719	153.940	81	1.654	113.210	81	1.672	100.430	81	1.672	80.563	81	1.6158	117.32
82	2.752	155.180	82	1.676	114.900	82	1.693	101.950	82	1.692	81.934	82	1.6366	118.92
83	2.787	156.570	83	1.697	116.570	83	1.715	103.500	83	1.714	83.351	83	1.6575	120.44
84	2.824	157.700	84	1.718	118.200	84	1.736	105.020	84	1.735	84.687	84	1.6782	121.91
85	2.859	158.830	85	1.739	119.920	85	1.758	106.600	85	1.756	86.021	85	1.6992	123.37
86	2.894	159.960	86	1.761	121.480	86	1.779	108.160	86	1.778	87.427	86	1.72	124.8
			87	1.782	123.030	87	1.800	109.740	87	1.799	88.774	87	1.741	126.17
			88	1.803	124.730	88	1.822	111.360	88	1.821	90.108	88	1.7617	127.6
			89	1.825	126.300	89	1.843	112.970	89	1.842	91.532	89	1.7824	128.93
			90	1.845	127.930	90	1.864	114.600	90	1.863	92.944	90	1.8033	130.25
			91	1.867	129.510	91	1.885	116.240	91	1.885	94.360	91	1.8241	131.46
			92	1.888	131.060	92	1.907	117.900	92	1.906	95.790	92	1.8448	132.65
			93	1.909	132.650	93	1.929	119.590	93	1.928	97.153	93	1.8658	133.89
			94	1.930	134.140	94	1.950	121.250	94	1.949	98.549	94	1.8866	135.07
			95	1.951	135.670	95	1.971	122.940	95	1.971	99.958	95	1.9077	136.12
			96	1.974	137.210	96	1.992	124.610	96	1.991	101.280	96	1.9284	137.3
			97	1.994	138.690	97	2.014	126.280	97	2.014	102.670	97	1.9491	138.39
			98	2.015	140.180	98	2.035	127.970	98	2.035	104.060	98	1.9701	139.46
			99	2.038	141.610	99	2.057	129.690	99	2.057	105.500	99	1.9909	140.56
			100	2.058	143.000	100	2.079	131.340	100	2.078	106.920	100	2.0115	141.6
			101	2.080	144.380	101	2.100	132.960	101	2.100	108.320	101	2.0324	142.68
			102	2.101	145.730	102	2.122	134.550	102	2.122	109.770	102	2.0533	143.75
			103	2.122	147.080	103	2.143	136.120	103	2.143	111.310	103	2.0742	144.71
			104	2.145	148.170	104	2.165	137.660	104	2.164	112.740	104	2.095	145.75
			105	2.166	149.470	105	2.186	139.150	105	2.186	114.180	105	2.1159	146.67
			106	2.186	150.800	106	2.208	140.690	106	2.208	115.690	106	2.1368	147.57
			107	2.208	152.010	107	2.229	142.170	107	2.228	117.160	107	2.1575	148.38
			108	2.229	152.920	108	2.251	143.570	108	2.250	118.700	108	2.1782	149.08
			109	2.250	153.410	109	2.272	144.990	109	2.272	120.230	109	2.199	149.95
			110	2.272	153.200	110	2.294	146.380	110	2.293	121.780	110	2.2199	150.27
			111	2.293	152.570	111	2.316	147.730	111	2.316	123.280	111	2.2401	150.66
			112	2.315	152.090	112	2.337	148.990	112	2.336	124.620	112	2.2608	150.88
						113	2.358	150.230	113	2.358	126.120	113	2.2817	151.58
						114	2.379	151.210	114	2.379	127.590	114	2.3025	152.42
						115	2.401	152.380	115	2.401	129.070			
						116	2.423	153.630	116	2.422	130.540			
						117	2.445	154.570	117	2.444	131.910			
						118	2.466	155.330	118	2.466	133.340			
									119	2.487	134.790			
									120	2.508	136.170			
									121	2.530	137.550			
									122	2.552	138.860			
									123	2.573	140.200			
									124	2.594	141.540			
									125	2.615	142.850			
									126	2.637	144.210			
									127	2.659	145.510			
									128	2.680	146.680			
									129	2.702	147.900			
									130	2.723	148.940			
									131	2.745	150.100			
									132	2.766	151.240			

C-5. MWCNT, Bamboo D = 30+/-15nm, L = 1-5 micron

MWCNT-E (01)			MWCNT-E (02)			MWCNT-E (03)			MWCNT-E (04)			MWCNT-E (05)		
Point	Strain(%)	Stress(Mpa)	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress
1	0.000	-0.146	1	0.000	1.179	1	0.000	-0.018	1	0.000	-0.033	1	0.000	-0.081
2	0.000	-0.142	2	0.000	1.190	2	0.000	-0.018	2	0.000	-0.036	2	0.000	-0.076
3	0.000	-0.142	3	0.000	1.188	3	0.000	-0.027	3	0.000	-0.020	3	0.000	-0.085
4	0.018	0.253	4	0.008	1.371	4	0.000	-0.015	4	0.004	0.150	4	0.014	0.518
5	0.055	0.251	5	0.029	1.864	5	0.011	0.352	5	0.026	0.766	5	0.036	0.768
6	0.092	0.253	6	0.051	2.310	6	0.034	0.483	6	0.048	0.836	6	0.058	0.858
7	0.127	0.246	7	0.074	2.726	7	0.057	0.638	7	0.072	1.055	7	0.081	1.044
8	0.165	0.927	8	0.096	3.107	8	0.079	1.098	8	0.094	1.352	8	0.102	1.324
9	0.202	2.378	9	0.118	3.536	9	0.101	1.706	9	0.116	1.940	9	0.124	1.711
10	0.237	3.895	10	0.140	4.170	10	0.124	2.338	10	0.139	2.758	10	0.144	2.317
11	0.273	5.454	11	0.162	4.884	11	0.146	2.980	11	0.161	3.546	11	0.165	2.972
12	0.310	7.002	12	0.185	5.685	12	0.168	3.572	12	0.183	4.345	12	0.187	3.637
13	0.346	8.556	13	0.206	6.558	13	0.190	4.224	13	0.204	5.151	13	0.208	4.339
14	0.382	9.960	14	0.228	7.478	14	0.212	4.965	14	0.226	5.957	14	0.229	5.030
15	0.416	10.919	15	0.250	8.426	15	0.234	5.757	15	0.248	6.766	15	0.251	5.788
16	0.452	11.985	16	0.271	9.421	16	0.256	6.671	16	0.270	7.553	16	0.272	6.489
17	0.489	13.658	17	0.291	10.395	17	0.277	7.618	17	0.292	8.271	17	0.293	7.162
18	0.524	15.324	18	0.314	11.372	18	0.299	8.624	18	0.314	8.913	18	0.313	7.782
19	0.559	17.163	19	0.335	12.216	19	0.321	9.769	19	0.335	9.540	19	0.334	8.340
20	0.594	19.257	20	0.356	12.784	20	0.342	10.985	20	0.358	10.347	20	0.356	8.932
21	0.629	21.498	21	0.378	13.133	21	0.364	12.177	21	0.379	11.178	21	0.376	9.637
22	0.664	23.932	22	0.399	13.530	22	0.385	13.278	22	0.401	12.010	22	0.397	10.545
23	0.699	26.469	23	0.420	14.192	23	0.407	14.207	23	0.422	12.893	23	0.418	11.700
24	0.734	28.924	24	0.442	14.976	24	0.429	14.604	24	0.444	13.772	24	0.439	12.867
25	0.770	31.516	25	0.462	15.806	25	0.450	14.626	25	0.466	14.656	25	0.460	14.027
26	0.804	34.161	26	0.485	16.751	26	0.471	14.621	26	0.487	15.577	26	0.481	15.247
27	0.839	36.829	27	0.506	17.694	27	0.494	15.000	27	0.509	16.519	27	0.501	16.503
28	0.875	39.437	28	0.527	18.892	28	0.515	16.196	28	0.531	17.796	28	0.522	17.801
29	0.910	42.051	29	0.549	20.153	29	0.536	17.724	29	0.552	19.077	29	0.543	19.140
30	0.944	44.546	30	0.569	21.408	30	0.557	19.303	30	0.573	20.363	30	0.563	20.409
31	0.979	46.986	31	0.591	22.791	31	0.579	20.847	31	0.595	21.685	31	0.584	21.730
32	1.014	49.434	32	0.613	24.226	32	0.600	22.439	32	0.616	22.997	32	0.605	22.993
33	1.049	51.855	33	0.633	25.596	33	0.621	23.997	33	0.638	24.311	33	0.626	24.276
34	1.084	54.174	34	0.655	27.038	34	0.642	25.558	34	0.659	25.727	34	0.647	25.566
35	1.118	56.509	35	0.676	28.544	35	0.664	27.101	35	0.681	27.087	35	0.667	26.863
36	1.153	58.796	36	0.697	30.060	36	0.685	28.619	36	0.703	28.476	36	0.688	28.232
37	1.188	61.130	37	0.718	31.605	37	0.706	30.129	37	0.724	29.836	37	0.708	29.535
38	1.223	63.444	38	0.739	33.125	38	0.728	31.620	38	0.746	31.155	38	0.730	30.868
39	1.258	65.708	39	0.761	34.685	39	0.749	33.103	39	0.767	32.497	39	0.751	32.231
40	1.293	67.988	40	0.782	36.258	40	0.771	34.573	40	0.790	33.831	40	0.771	33.495
41	1.328	70.293	41	0.803	37.786	41	0.792	35.997	41	0.810	35.125	41	0.792	34.809
42	1.361	72.502	42	0.824	39.389	42	0.814	37.420	42	0.832	36.491	42	0.8125	36.081
43	1.396	74.691	43	0.846	40.977	43	0.835	38.851	43	0.853	37.812	43	0.83313	37.332
44	1.432	76.900	44	0.867	42.505	44	0.857	40.223	44	0.875	39.173	44	0.85417	38.609
45	1.465	79.079	45	0.888	44.089	45	0.878	41.616	45	0.897	40.510	45	0.87413	39.861
46	1.500	81.230	46	0.908	45.605	46	0.900	42.986	46	0.918	41.825	46	0.89517	41.105
47	1.535	83.326	47	0.930	47.166	47	0.921	44.366	47	0.940	43.161	47	0.9157	42.395
48	1.570	85.459	48	0.952	48.736	48	0.942	45.730	48	0.961	44.505	48	0.93667	43.597
49	1.606	87.591	49	0.973	50.211	49	0.963	47.068	49	0.983	45.777	49	0.9566	44.85
50	1.640	89.559	50	0.995	51.800	50	0.985	48.432	50	1.004	47.115	50	0.97747	46.054
51	1.675	91.538	51	1.016	53.356	51	1.007	49.769	51	1.026	48.452	51	0.9982	47.294
52	1.710	93.474	52	1.038	54.837	52	1.028	51.059	52	1.047	49.768	52	1.0191	48.541
53	1.745	95.438	53	1.059	56.393	53	1.050	52.346	53	1.068	51.096	53	1.0399	49.759
54	1.780	97.385	54	1.079	57.817	54	1.071	53.557	54	1.090	52.412	54	1.0601	51.031
55	1.815	99.263	55	1.101	59.335	55	1.093	54.791	55	1.111	53.736	55	1.0816	52.34
56	1.849	101.160	56	1.123	60.813	56	1.114	56.070	56	1.133	55.055	56	1.1017	53.584
57	1.884	103.030	57	1.144	62.238	57	1.136	57.324	57	1.154	56.204	57	1.1233	54.964
58	1.919	104.820	58	1.165	63.738	58	1.157	58.596	58	1.176	57.464	58	1.1441	56.31
59	1.954	106.630	59	1.186	65.218	59	1.179	59.893	59	1.197	58.732	59	1.1649	57.665
60	1.989	108.320	60	1.208	66.654	60	1.200	61.165	60	1.219	60.032	60	1.1858	58.972
61	2.024	110.040	61	1.229	68.118	61	1.222	62.440	61	1.241	61.348	61	1.2066	60.333
62	2.060	111.690	62	1.250	69.439	62	1.243	63.706	62	1.262	62.630	62	1.2267	61.696
63	2.094	113.230	63	1.271	70.799	63	1.264	65.000	63	1.284	63.955	63	1.2484	63.177
64	2.130	114.820	64	1.292	72.236	64	1.286	66.257	64	1.305	65.316	64	1.2683	64.571
65	2.165	116.430	65	1.313	73.592	65	1.307	67.471	65	1.327	66.640	65	1.2892	66.006
66	2.200	118.050	66	1.335	75.048	66	1.329	68.738	66	1.348	68.041	66	1.3108	67.469
67	2.235	119.630	67	1.356	76.488	67	1.350	70.000	67	1.370	69.449	67	1.3315	68.884
68	2.269	121.130	68	1.377	77.853	68	1.372	71.253	68	1.391	70.871	68	1.3517	70.333
69	2.304	122.680	69	1.398	79.331	69	1.393	72.539	69	1.412	72.320	69	1.3733	71.774
70	2.339	124.340	70	1.420	80.796	70	1.414	73.768	70	1.434	73.784	70	1.3933	73.182
71	2.374	125.920	71	1.442	82.258	71	1.435	75.041	71	1.454	75.276	71	1.4151	74.716
72	2.409	127.580	72	1.463	83.707	72	1.457	76.316	72	1.476	76.757	72	1.435	76.132
73	2.445	129.290	73	1.485	85.032	73	1.478	77.560	73	1.497	78.237	73	1.4559	77.61
74	2.480	130.840	74	1.506	86.512	74	1.500	78.837	74	1.519	79.803	74	1.4774	79.151

75	2.515	132.390	75	1.527	87.862	75	1.521	80.098	75	1.540	81.333	75	1.4982	80.593
76	2.550	133.850	76	1.549	89.207	76	1.543	81.358	76	1.561	82.814	76	1.5183	82.093
77	2.584	135.170	77	1.570	90.677	77	1.564	82.660	77	1.583	84.421	77	1.54	83.625
78	2.620	136.390	78	1.591	92.036	78	1.585	83.963	78	1.604	85.977	78	1.5608	85.141
79	2.654	137.340	79	1.613	93.405	79	1.607	85.297	79	1.625	87.452	79	1.5819	86.734
80	2.691	138.310	80	1.635	94.863	80	1.628	86.585	80	1.647	89.005	80	1.6026	88.258
81	2.726	139.230	81	1.656	96.177	81	1.650	87.890	81	1.668	90.470	81	1.6234	89.78
82	2.759	140.130	82	1.677	97.566	82	1.671	89.190	82	1.690	92.011	82	1.644	91.346
83	2.794	140.970	83	1.698	98.982	83	1.693	90.495	83	1.711	93.523	83	1.6649	92.861
84	2.829	141.620	84	1.720	100.310	84	1.714	91.801	84	1.733	95.073	84	1.6859	94.431
85	2.866	142.230	85	1.741	101.710	85	1.735	93.099	85	1.754	96.703	85	1.7066	95.952
86	2.899	142.660	86	1.762	103.030	86	1.756	94.379	86	1.776	98.370	86	1.7275	97.424
87	2.934	143.000	87	1.784	104.360	87	1.778	95.673	87	1.797	100.100	87	1.7485	98.954
88	2.969	143.190	88	1.805	105.660	88	1.799	96.989	88	1.819	101.810	88	1.7692	100.42
89	3.004	143.270	89	1.827	106.900	89	1.821	98.286	89	1.840	103.460	89	1.7899	101.93
90	3.039	143.470	90	1.848	108.170	90	1.842	99.645	90	1.862	105.330	90	1.8108	103.43
91	3.074	143.620	91	1.870	109.490	91	1.864	100.980	91	1.884	107.180	91	1.8317	104.89
92	3.108	143.620	92	1.891	110.700	92	1.884	102.370	92	1.905	109.090	92	1.8525	106.37
93	3.143	143.610	93	1.912	112.010	93	1.906	103.760	93	1.927	111.050	93	1.8724	107.87
94	3.178	143.590	94	1.934	113.130	94	1.927	105.130	94	1.947	113.010	94	1.8933	109.4
95	3.213	143.640	95	1.956	114.380	95	1.949	106.540	95	1.969	114.960	95	1.9151	110.99
96	3.248	143.980	96	1.977	115.610	96	1.970	107.950	96	1.991	116.960	96	1.9359	112.47
97	3.283	144.420	97	1.997	116.720	97	1.991	109.360	97	2.012	118.970	97	1.9567	114
98	3.318	145.120	98	2.019	117.950	98	2.013	110.780	98	2.034	121.030	98	1.9774	115.53
99	3.353	146.320	99	2.040	119.120	99	2.034	112.230	99	2.056	123.070	99	1.9983	116.96
100	3.388	147.720	100	2.062	120.270	100	2.056	113.660	100	2.077	125.010	100	2.0191	118.47
101	3.423	149.100	101	2.083	121.490	101	2.077	115.200	101	2.098	127.100	101	2.0399	119.88
102	3.458	150.180	102	2.103	122.600	102	2.099	116.740	102	2.120	129.110	102	2.0608	121.26
			103	2.125	123.730	103	2.120	118.310	103	2.141	131.190	103	2.0818	122.7
			104	2.147	124.910	104	2.142	119.940	104	2.162	133.240	104	2.1026	124.05
			105	2.167	125.920	105	2.162	121.580	105	2.184	135.250	105	2.1234	125.43
			106	2.188	127.040	106	2.184	123.260	106	2.205	137.310	106	2.1441	126.74
			107	2.209	128.180	107	2.205	124.940	107	2.227	139.380	107	2.165	127.97
			108	2.231	129.190	108	2.227	126.620	108	2.248	141.420	108	2.1858	129.2
			109	2.252	130.270	109	2.248	128.320	109	2.270	143.520	109	2.2058	130.33
			110	2.274	131.370	110	2.269	129.990	110	2.291	145.550	110	2.2267	131.46
			111	2.295	132.340	111	2.290	131.650	111	2.313	147.610	111	2.2476	132.59
			112	2.317	133.340	112	2.312	133.340	112	2.335	149.620	112	2.2683	133.58
			113	2.338	134.170	113	2.333	134.950	113	2.355	151.510	113	2.2892	134.5
			114	2.359	135.090	114	2.354	136.600	114	2.378	153.520	114	2.3099	135.47
			115	2.380	136.020	115	2.376	138.260	115	2.399	155.450	115	2.3308	136.35
			116	2.402	136.880	116	2.397	139.900	116	2.420	157.310	116	2.3517	137.32
			117	2.423	137.830	117	2.418	141.530	117	2.441	159.220	117	2.3725	138.22
			118	2.444	138.630	118	2.439	143.160	118	2.463	161.000	118	2.3925	139.1
			119	2.465	139.480	119	2.461	144.770	119	2.485	162.750	119	2.4143	140
			120	2.487	140.380	120	2.482	146.360	120	2.507	164.480	120	2.4342	140.79
			121	2.509	141.140	121	2.504	147.930	121	2.528	166.030	121	2.455	141.59
			122	2.529	141.930	122	2.525	149.440	122	2.549	167.670	122	2.4758	142.35
			123	2.550	142.720	123	2.547	150.920	123	2.571	169.010	123	2.4967	143.02
			124	2.572	143.270	124	2.568	152.300				124	2.5175	143.73
			125	2.593	144.150	125	2.590	153.380				125	2.5383	144.31
			126	2.615	145.010	126	2.610	154.100				126	2.5583	144.85
			127	2.635	145.960	127	2.632	155.120				127	2.5792	145.44
			128	2.656	146.890							128	2.6	145.95
			129	2.678	147.820							129	2.6208	146.49
			130	2.699	148.870							130	2.6417	146.99
			131	2.721	149.870							131	2.6617	147.33
			132	2.742	150.840							132	2.6825	147.71
			133	2.764	151.930							133	2.7033	148.01
			134	2.785	153.000							134	2.7241	148.17
			135	2.806	154.120									
			136	2.828	155.240									
			137	2.849	156.290									
			138	2.871	157.460									
			139	2.892	158.580									
			140	2.913	159.710									
			141	2.934	160.860									
			142	2.956	161.820									

C-6. MWCNT, Bamboo D = 30+/-15nm, L = 5-20 micron

MWCNT-F (01)			MWCNT-F (02)			MWCNT-F (03)			MWCNT-F (05)		
Point	Strain(%)	Stress(Mpa)	Point	Strain(%)	Stress(Mpa)	Point	Strain(%)	Stress(Mpa)	Point	Strain(%)	Stress(Mpa)
1	0.000	0.166	1	0.000	1.483	1	0.000	-0.189	1	0.000	0.226
2	0.000	0.171	2	0.000	1.487	2	0.000	-0.189	2	0.000	0.218
3	0.000	0.156	3	0.000	1.487	3	0.000	-0.183	3	0.000	0.221
4	0.005	0.276	4	0.009	2.109	4	0.007	-0.052	4	0.005	0.315
5	0.041	0.686	5	0.030	2.662	5	0.029	0.057	5	0.028	0.475
6	0.076	1.339	6	0.051	2.844	6	0.051	0.181	6	0.050	0.616
7	0.114	2.298	7	0.074	3.242	7	0.074	0.264	7	0.071	0.871
8	0.151	3.512	8	0.097	3.713	8	0.097	0.492	8	0.094	1.266
9	0.186	4.722	9	0.119	4.398	9	0.119	0.824	9	0.116	1.858
10	0.223	6.147	10	0.141	5.183	10	0.141	1.209	10	0.137	2.529
11	0.260	7.612	11	0.162	5.865	11	0.164	1.728	11	0.159	3.251
12	0.297	8.990	12	0.185	6.637	12	0.186	2.261	12	0.180	4.016
13	0.332	10.081	13	0.207	7.515	13	0.208	2.806	13	0.202	4.842
14	0.369	11.116	14	0.227	8.409	14	0.230	3.375	14	0.223	5.658
15	0.404	12.663	15	0.251	9.344	15	0.252	3.953	15	0.244	6.446
16	0.439	14.559	16	0.271	10.162	16	0.274	4.538	16	0.265	7.276
17	0.475	16.649	17	0.293	11.027	17	0.296	5.110	17	0.286	8.002
18	0.510	18.943	18	0.315	12.088	18	0.317	5.681	18	0.308	8.680
19	0.545	21.341	19	0.336	13.224	19	0.339	6.343	19	0.329	9.301
20	0.581	23.815	20	0.358	14.539	20	0.360	7.093	20	0.350	9.943
21	0.616	26.407	21	0.379	15.782	21	0.382	7.954	21	0.371	10.625
22	0.651	29.101	22	0.400	16.952	22	0.403	8.885	22	0.392	11.314
23	0.686	31.766	23	0.421	18.054	23	0.425	9.883	23	0.414	12.030
24	0.722	34.367	24	0.443	19.064	24	0.446	10.920	24	0.434	12.825
25	0.757	36.886	25	0.464	20.147	25	0.467	11.883	25	0.455	13.748
26	0.792	39.392	26	0.485	21.181	26	0.489	12.809	26	0.476	15.016
27	0.828	41.845	27	0.505	22.165	27	0.510	13.747	27	0.497	16.306
28	0.863	44.203	28	0.527	23.253	28	0.532	14.691	28	0.518	17.641
29	0.898	46.528	29	0.549	24.231	29	0.553	15.558	29	0.540	19.118
30	0.934	48.780	30	0.569	25.216	30	0.575	16.442	30	0.561	20.616
31	0.969	50.977	31	0.591	26.339	31	0.597	17.451	31	0.582	22.181
32	1.004	53.160	32	0.612	27.666	32	0.619	18.564	32	0.602	23.791
33	1.040	55.269	33	0.633	29.086	33	0.640	19.967	33	0.624	25.331
34	1.075	57.453	34	0.655	30.536	34	0.661	21.403	34	0.645	26.944
35	1.110	59.577	35	0.675	31.934	35	0.684	22.891	35	0.666	28.471
36	1.146	61.551	36	0.697	33.443	36	0.705	24.360	36	0.687	30.040
37	1.181	63.565	37	0.718	34.851	37	0.726	25.796	37	0.708	31.678
38	1.218	65.594	38	0.739	36.225	38	0.748	27.239	38	0.729	33.247
39	1.251	67.515	39	0.762	37.703	39	0.769	28.662	39	0.750	34.847
40	1.287	69.440	40	0.783	39.079	40	0.791	30.091	40	0.770	36.525
41	1.322	71.329	41	0.803	40.435	41	0.812	31.522	41	0.792	38.107
42	1.357	73.337	42	0.826	41.844	42	0.834	32.886	42	0.81264	39.783
43	1.393	75.270	43	0.846	43.133	43	0.855	34.279	43	0.83445	41.406
44	1.428	77.136	44	0.868	44.555	44	0.877	35.635	44	0.85462	43.024
45	1.463	79.003	45	0.890	45.907	45	0.898	36.976	45	0.87654	44.69
46	1.499	80.905	46	0.910	47.209	46	0.920	38.345	46	0.89745	46.349
47	1.534	82.771	47	0.932	48.629	47	0.941	39.662	47	0.91778	47.941
48	1.569	84.683	48	0.953	49.973	48	0.963	40.997	48	0.93956	49.659
49	1.605	86.619	49	0.974	51.325	49	0.984	42.327	49	0.95963	51.294
50	1.640	88.586	50	0.996	52.693	50	1.006	43.625	50	0.98145	52.991
51	1.675	90.534	51	1.016	53.944	51	1.028	44.953	51	1.0025	54.716
52	1.710	92.456	52	1.038	55.287	52	1.050	46.208	52	1.0235	56.389
53	1.746	94.363	53	1.059	56.607	53	1.071	47.431	53	1.0446	58.105
54	1.781	96.268	54	1.080	57.843	54	1.092	48.747	54	1.0655	59.818
55	1.816	98.106	55	1.102	59.213	55	1.115	50.058	55	1.0858	61.493
56	1.852	99.980	56	1.122	60.458	56	1.136	51.354	56	1.1076	63.25
57	1.887	101.810	57	1.144	61.712	57	1.157	52.638	57	1.1285	64.946
58	1.922	103.720	58	1.165	62.983	58	1.178	53.889	58	1.1496	66.656
59	1.958	105.600	59	1.186	64.140	59	1.200	55.209	59	1.1698	68.369
60	1.993	107.510	60	1.209	65.418	60	1.222	56.509	60	1.1907	70.069
61	2.028	109.350	61	1.230	66.685	61	1.243	57.776	61	1.2126	71.845
62	2.064	111.260	62	1.251	67.851	62	1.265	59.051	62	1.2336	73.56
63	2.098	113.170	63	1.273	69.144	63	1.286	60.318	63	1.2539	75.21
64	2.133	115.170	64	1.294	70.359	64	1.308	61.579	64	1.2757	76.996
65	2.168	117.130	65	1.315	71.590	65	1.328	62.813	65	1.2965	78.715
66	2.203	119.240	66	1.337	72.842	66	1.350	64.035	66	1.3177	80.473
67	2.237	121.390	67	1.358	74.027	67	1.372	65.294	67	1.3387	82.219
68	2.273	123.610	68	1.380	75.289	68	1.393	66.542	68	1.3596	83.969
69	2.308	125.850	69	1.401	76.497	69	1.415	67.761	69	1.3807	85.773
70	2.343	128.180	70	1.421	77.707	70	1.436	69.023	70	1.4016	87.621
71	2.379	130.440	71	1.444	79.060	71	1.458	70.270	71	1.4219	89.426
72	2.414	132.660	72	1.465	80.318	72	1.479	71.515	72	1.4437	91.33
73	2.449	134.860	73	1.486	81.629	73	1.501	72.757	73	1.4647	93.209
74	2.485	137.030	74	1.508	82.954	74	1.522	73.920	74	1.4849	95.106
75	2.520	139.100	75	1.528	84.198	75	1.544	75.121	75	1.5058	97.026
76	2.555	141.010	76	1.551	85.543	76	1.566	76.343	76	1.5268	98.928

77	2.589	142.810	77	1.572	86.863	77	1.587	77.541	77	1.548	100.92
78	2.624	144.590	78	1.592	88.088	78	1.609	78.815	78	1.5688	102.89
79	2.660	146.290	79	1.615	89.463	79	1.630	80.089	79	1.5891	104.77
			80	1.636	90.775	80	1.652	81.374	80	1.611	106.76
			81	1.657	92.068	81	1.673	82.706	81	1.6319	108.67
			82	1.679	93.342	82	1.694	84.037	82	1.6521	110.55
			83	1.700	94.575	83	1.716	85.386	83	1.6731	112.45
			84	1.721	95.894	84	1.737	86.742	84	1.6941	114.26
			85	1.743	97.168	85	1.759	88.112	85	1.7151	116.09
			86	1.764	98.363	86	1.780	89.488	86	1.7361	117.89
			87	1.786	99.671	87	1.802	90.869	87	1.7563	119.53
			88	1.807	100.900	88	1.823	92.224	88	1.7773	121.22
			89	1.827	102.190	89	1.845	93.608	89	1.7983	122.87
			90	1.850	103.440	90	1.866	94.987	90	1.8193	124.5
			91	1.870	104.590	91	1.887	96.352	91	1.8403	126.1
			92	1.892	105.850	92	1.909	97.706	92	1.8604	127.59
			93	1.913	107.080	93	1.930	99.056	93	1.8824	129.13
			94	1.933	108.220	94	1.952	100.430	94	1.9025	130.6
			95	1.955	109.480	95	1.974	101.810	95	1.9227	132
			96	1.976	110.670	96	1.995	103.150	96	1.9447	133.57
			97	1.998	111.820	97	2.016	104.490	97	1.9655	135.09
			98	2.019	112.980	98	2.038	105.840	98	1.9858	136.57
			99	2.039	114.110	99	2.060	107.150	99	2.0067	138.05
			100	2.062	115.310	100	2.081	108.490	100	2.0268	139.44
			101	2.083	116.420	101	2.102	109.800	101	2.0487	140.94
			102	2.104	117.470	102	2.123	111.130	102	2.0697	142.37
			103	2.126	118.640	103	2.145	112.460	103	2.0899	143.69
			104	2.147	119.720	104	2.166	113.770	104	2.1111	145.12
			105	2.168	120.830	105	2.187	115.100	105	2.1319	146.45
			106	2.190	121.960	106	2.209	116.400	106	2.1529	147.71
			107	2.210	123.010	107	2.230	117.730	107	2.1739	148.98
			108	2.232	124.170	108	2.252	119.040	108	2.1949	150.07
			109	2.253	125.280	109	2.272	120.310	109	2.216	151.18
			110	2.274	126.330	110	2.294	121.640	110	2.2369	152.24
			111	2.296	127.470	111	2.316	123.020	111	2.2563	153.25
			112	2.317	128.540	112	2.337	124.360	112	2.2782	154.39
			113	2.339	129.660	113	2.359	125.760	113	2.2983	155.44
			114	2.360	130.750	114	2.380	127.160	114	2.3193	156.48
			115	2.380	131.750	115	2.402	128.540	115	2.3403	157.53
			116	2.402	132.890	116	2.423	129.940	116	2.3604	158.49
			117	2.423	134.020	117	2.445	131.330	117	2.3815	159.37
			118	2.444	135.090	118	2.466	132.740	118	2.4025	160.1
			119	2.466	136.300	119	2.488	134.190			
			120	2.487	137.400	120	2.510	135.660			
			121	2.509	138.500	121	2.531	137.140			
			122	2.530	139.600	122	2.553	138.610			
			123	2.551	140.680	123	2.574	140.080			
			124	2.573	141.800	124	2.596	141.590			
			125	2.594	142.900	125	2.617	143.060			
			126	2.615	143.950	126	2.638	144.530			
			127	2.637	145.100	127	2.660	146.000			
			128	2.658	146.170	128	2.681	147.460			
			129	2.680	147.280	129	2.703	148.880			
			130	2.701	148.400	130	2.724	150.350			
			131	2.721	149.430	131	2.746	151.770			
			132	2.743	150.550	132	2.768	153.180			
			133	2.764	151.680	133	2.790	154.510			
			134	2.785	152.370	134	2.811	155.830			
			135	2.807	153.460	135	2.833	157.170			
			136	2.827	154.500	136	2.854	158.400			
			137	2.849	155.500	137	2.876	159.630			
			138	2.870	156.480	138	2.897	160.830			
						139	2.919	161.910			
						140	2.941	162.950			
						141	2.962	163.900			

C-7. SWCNT, D = 1-1.5nm, L = 1-10 micron

	SWCNT	(01)		SWCNT	(02)		SWCNT	(03)		SWCNT	(04)		SWCNT	(05)
Point	Strain(%)	Stress(Mpa)	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress
1	0.000	1.305	1	0.000	2.805	1	0.000	0.094	1	0.000	0.026	1	0.000	-0.010
2	0.000	1.293	2	0.000	2.807	2	0.000	0.082	2	0.000	0.022	2	0.000	-0.006
3	0.000	1.294	3	0.000	2.809	3	0.000	0.083	3	0.000	0.021	3	0.000	-0.008
4	0.000	1.288	4	0.007	3.352	4	0.004	0.095	4	0.008	0.536	4	0.011	0.441
5	0.024	2.617	5	0.031	4.290	5	0.020	0.174	5	0.030	0.772	5	0.033	0.866
6	0.063	4.704	6	0.052	5.089	6	0.043	0.391	6	0.051	1.029	6	0.055	0.980
7	0.098	6.741	7	0.074	5.993	7	0.066	0.966	7	0.072	1.596	7	0.077	1.149
8	0.137	9.028	8	0.097	7.049	8	0.089	1.691	8	0.095	2.308	8	0.099	1.426
9	0.172	11.376	9	0.119	8.143	9	0.111	2.373	9	0.116	3.022	9	0.121	1.778
10	0.209	13.806	10	0.142	9.434	10	0.134	3.067	10	0.138	3.885	10	0.143	2.178
11	0.247	16.393	11	0.163	10.643	11	0.156	3.789	11	0.158	4.772	11	0.165	2.678
12	0.282	18.917	12	0.185	11.787	12	0.178	4.468	12	0.180	5.748	12	0.186	3.213
13	0.319	21.426	13	0.208	12.849	13	0.201	5.209	13	0.201	6.786	13	0.208	3.727
14	0.356	23.793	14	0.228	13.959	14	0.222	6.094	14	0.220	7.829	14	0.230	4.255
15	0.390	26.012	15	0.250	15.329	15	0.244	7.016	15	0.242	8.975	15	0.250	4.797
16	0.427	28.859	16	0.272	16.510	16	0.267	7.992	16	0.262	10.055	16	0.271	5.356
17	0.464	31.759	17	0.292	17.576	17	0.288	8.946	17	0.284	11.284	17	0.292	5.893
18	0.500	34.565	18	0.315	18.648	18	0.309	9.973	18	0.304	12.644	18	0.314	6.438
19	0.536	37.508	19	0.335	19.615	19	0.331	11.098	19	0.325	13.983	19	0.335	6.948
20	0.571	40.378	20	0.357	20.682	20	0.353	12.315	20	0.345	15.369	20	0.356	7.384
21	0.607	43.234	21	0.379	21.828	21	0.375	13.623	21	0.366	16.756	21	0.378	7.771
22	0.642	46.130	22	0.399	23.036	22	0.397	14.795	22	0.385	18.120	22	0.399	8.073
23	0.678	48.885	23	0.421	24.505	23	0.418	15.546	23	0.407	19.684	23	0.420	8.788
24	0.714	51.729	24	0.442	25.980	24	0.440	16.109	24	0.427	21.325	24	0.441	9.806
25	0.749	54.544	25	0.463	27.386	25	0.461	17.175	25	0.448	22.938	25	0.462	10.865
26	0.786	57.210	26	0.485	28.867	26	0.483	18.693	26	0.468	24.609	26	0.483	11.983
27	0.822	59.941	27	0.506	30.294	27	0.505	20.246	27	0.488	26.256	27	0.504	13.079
28	0.858	62.657	28	0.527	31.679	28	0.527	21.754	28	0.509	27.975	28	0.525	14.209
29	0.893	65.321	29	0.549	33.173	29	0.548	23.342	29	0.529	29.738	29	0.546	15.353
30	0.929	67.971	30	0.570	34.608	30	0.570	24.907	30	0.549	31.385	30	0.568	16.480
31	0.965	70.546	31	0.592	36.111	31	0.591	26.495	31	0.571	33.128	31	0.589	17.642
32	1.000	73.246	32	0.613	37.582	32	0.613	28.088	32	0.590	34.864	32	0.610	18.711
33	1.036	75.898	33	0.634	38.980	33	0.634	29.635	33	0.611	36.617	33	0.631	19.921
34	1.071	78.431	34	0.656	40.475	34	0.656	31.226	34	0.631	38.377	34	0.652	21.186
35	1.107	81.112	35	0.677	41.869	35	0.678	32.815	35	0.652	40.115	35	0.673	22.483
36	1.143	83.743	36	0.698	43.241	36	0.698	34.347	36	0.672	41.877	36	0.694	23.837
37	1.178	86.432	37	0.720	44.706	37	0.721	35.920	37	0.693	43.636	37	0.715	25.227
38	1.214	89.089	38	0.741	46.054	38	0.741	37.463	38	0.712	45.306	38	0.736	26.701
39	1.249	91.810	39	0.763	47.510	39	0.763	38.975	39	0.733	47.024	39	0.758	28.183
40	1.285	94.672	40	0.784	48.851	40	0.784	40.550	40	0.753	48.743	40	0.778	29.619
41	1.321	97.644	41	0.804	50.119	41	0.806	42.077	41	0.774	50.403	41	0.800	31.117
42	1.355	100.540	42	0.826	51.534	42	0.828	43.659	42	0.794	52.055	42	0.82017	32.54
43	1.390	103.630	43	0.847	52.741	43	0.849	45.213	43	0.814	53.660	43	0.84121	34.03
44	1.426	106.690	44	0.868	53.998	44	0.871	46.731	44	0.834	55.284	44	0.86215	35.528
45	1.462	109.790	45	0.890	55.350	45	0.892	48.294	45	0.856	56.909	45	0.88319	37.016
46	1.496	112.870	46	0.910	56.553	46	0.914	49.812	46	0.875	58.441	46	0.9043	38.625
47	1.531	115.940	47	0.932	57.788	47	0.935	51.296	47	0.897	60.035	47	0.92521	40.215
48	1.567	119.130	48	0.953	59.011	48	0.957	52.768	48	0.917	61.614	48	0.94625	41.87
49	1.603	122.240	49	0.974	60.178	49	0.978	54.184	49	0.937	63.095	49	0.96803	43.548
50	1.638	125.210	50	0.997	61.424	50	1.000	55.650	50	0.958	64.633	50	0.98904	45.225
51	1.674	128.160	51	1.018	62.542	51	1.022	57.089	51	0.978	66.057	51	1.0093	46.944
52	1.709	130.960	52	1.039	63.609	52	1.043	58.500	52	0.998	67.523	52	1.0311	48.743
53	1.745	133.670	53	1.061	64.803	53	1.065	59.976	53	1.019	68.992	53	1.0521	50.498
54	1.781	136.250	54	1.082	65.866	54	1.086	61.372	54	1.039	70.392	54	1.0732	52.332
55	1.816	138.660	55	1.104	66.979	55	1.108	62.767	55	1.059	71.836	55	1.0941	54.203
56	1.852	140.940	56	1.125	68.153	56	1.129	64.176	56	1.079	73.259	56	1.1151	56.036
57	1.886	143.060	57	1.146	69.215	57	1.150	65.515	57	1.100	74.622	57	1.1361	58.004
58	1.922	144.940	58	1.168	70.425	58	1.171	66.918	58	1.121	75.986	58	1.1571	59.943
59	1.957	146.780	59	1.189	71.497	59	1.193	68.245	59	1.140	77.301	59	1.1773	61.882
60	1.993	148.320	60	1.209	72.554	60	1.215	69.545	60	1.161	78.618	60	1.1983	63.865
61	2.028	149.830	61	1.232	73.812	61	1.236	70.916	61	1.182	79.957	61	1.2193	65.856
62	2.064	151.030	62	1.253	74.921	62	1.258	72.215	62	1.202	81.210	62	1.2404	67.893
			63	1.274	76.028	63	1.279	73.515	63	1.222	82.489	63	1.2613	69.934
			64	1.296	77.278	64	1.300	74.879	64	1.243	83.760	64	1.2823	71.954
			65	1.317	78.365	65	1.322	76.216	65	1.263	84.995	65	1.3033	74.059
			66	1.339	79.629	66	1.343	77.609	66	1.284	86.256	66	1.3243	76.116
			67	1.360	80.796	67	1.365	79.018	67	1.304	87.478	67	1.3445	78.142
			68	1.380	81.916	68	1.386	80.359	68	1.325	88.700	68	1.3655	80.235
			69	1.403	83.172	69	1.408	81.830	69	1.345	89.977	69	1.3866	82.326
			70	1.424	84.299	70	1.429	83.258	70	1.365	91.108	70	1.4076	84.447
			71	1.445	85.447	71	1.451	84.745	71	1.385	92.318	71	1.4286	86.526
			72	1.467	86.724	72	1.473	86.304	72	1.406	93.547	72	1.4496	88.547
			73	1.488	87.883	73	1.494	87.804	73	1.426	94.728	73	1.4706	90.669
			74	1.509	89.234	74	1.516	89.404	74	1.447	95.953	74	1.4907	92.696
			75	1.531	90.510	75	1.537	91.041	75	1.467	97.111	75	1.5119	94.725
			76	1.552	91.769	76	1.559	92.656	76	1.488	98.293	76	1.5328	96.804
			77	1.574	93.203	77	1.580	94.363	77	1.508	99.495	77	1.5529	98.784
			78	1.595	94.494	78	1.601	96.052	78	1.528	100.620	78	1.5739	100.84
			79	1.615	95.848	79	1.623	97.749	79	1.548	101.820	79	1.595	102.8

			80	1.637	97.351	80	1.644	99.543	80	1.570	103.000	80	1.6161	104.77
			81	1.658	98.739	81	1.665	101.270	81	1.590	104.160	81	1.6361	106.75
			82	1.680	100.210	82	1.686	103.070	82	1.611	105.330	82	1.6572	108.63
			83	1.701	101.670	83	1.708	104.870	83	1.630	106.350	83	1.6781	110.51
			84	1.721	103.070	84	1.728	106.660	84	1.651	107.440	84	1.6992	112.35
			85	1.744	104.600	85	1.750	108.500	85	1.671	108.580	85	1.7193	114.13
			86	1.765	106.050	86	1.772	110.290	86	1.691	109.650	86	1.7403	115.96
			87	1.785	107.470	87	1.793	112.120	87	1.712	110.760	87	1.7614	117.65
			88	1.807	109.020	88	1.815	113.970	88	1.733	111.820	88	1.7824	119.34
			89	1.827	110.440	89	1.835	115.800	89	1.753	112.820	89	1.8033	120.95
			90	1.850	111.960	90	1.858	117.650	90	1.775	113.830	90	1.8244	122.54
			91	1.871	113.440	91	1.879	119.480	91	1.795	114.780	91	1.8445	124.04
			92	1.891	114.770	92	1.900	121.260	92	1.816	115.750	92	1.8655	125.54
			93	1.914	116.280	93	1.922	123.080	93	1.837	116.690	93	1.8866	126.93
			94	1.935	117.620	94	1.943	124.850	94	1.857	117.530	94	1.9084	128.31
			95	1.956	118.970	95	1.965	126.560	95	1.877	118.430	95	1.9286	129.57
			96	1.978	120.420	96	1.986	128.380	96	1.898	119.350	96	1.9496	130.81
			97	1.998	121.740	97	2.008	130.080	97	1.919	120.160	97	1.9706	132.05
			98	2.020	123.130	98	2.029	131.800	98	1.939	121.020	98	1.9916	133.27
			99	2.041	124.390	99	2.051	133.490	99	1.959	121.810	99	2.0117	134.4
			100	2.062	125.600	100	2.072	135.130	100	1.980	122.590	100	2.0328	135.6
			101	2.084	126.950	101	2.094	136.790	101	2.001	123.330	101	2.0529	136.73
			102	2.105	128.130	102	2.116	138.410	102	2.021	124.000	102	2.0739	137.78
			103	2.126	129.280	103	2.137	139.960	103	2.041	124.750	103	2.0951	138.8
			104	2.147	130.570	104	2.159	141.580	104	2.062	125.490	104	2.116	139.73
			105	2.168	131.720	105	2.180	143.040	105	2.082	126.110	105	2.1369	140.65
			106	2.190	132.920	106	2.202	144.390	106	2.103	126.810	106	2.1581	141.39
			107	2.211	134.080	107	2.223	145.240	107	2.124	127.460	107	2.1782	141.85
			108	2.232	135.080				108	2.144	128.120			
			109	2.254	136.150				109	2.165	128.760			
			110	2.275	137.190				110	2.185	129.390			
			111	2.296	138.200				111	2.206	130.020			
			112	2.318	139.130				112	2.226	130.660			
			113	2.339	140.000				113	2.247	131.220			
			114	2.361	141.000				114	2.267	131.840			
			115	2.382	141.810				115	2.288	132.390			
			116	2.403	142.630				116	2.308	133.030			
			117	2.425	143.540				117	2.329	133.630			
			118	2.446	144.290				118	2.348	134.120			
			119	2.467	144.560				119	2.369	134.700			
									120	2.389	135.230			
									121	2.410	135.720			
									122	2.430	136.330			
									123	2.451	136.830			
									124	2.471	137.400			
									125	2.491	137.930			
									126	2.511	138.440			
									127	2.532	139.020			
									128	2.552	139.510			
									129	2.573	139.950			
									130	2.593	140.420			
									131	2.614	140.770			
									132	2.634	141.150			
									133	2.655	141.510			
									134	2.675	141.790			
									135	2.696	142.090			
									136	2.716	142.350			
									137	2.736	142.580			
									138	2.757	142.880			
									139	2.777	143.120			
									140	2.798	143.360			

C-8. No Reinforcement

	NO CNT	(01)		NO CNT	(02)		NO CNT	(03)		NO CNT	(04)		NO CNT	(05)
Point	Strain(%)	Stress(Mpa)	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress	Pt	Strain	Stress
1	0.000	-0.251	1	0.000	1.697	1	0.000	0.076	1	0.000	0.686	1	0.000	-0.093
2	0.000	-0.240	2	0.000	1.699	2	0.000	0.072	2	0.000	0.678	2	0.000	-0.094
3	0.000	-0.238	3	0.000	1.707	3	0.000	0.076	3	0.000	0.674	3	0.000	-0.090
4	0.010	-0.101	4	0.006	1.829	4	0.006	0.204	4	0.009	1.028	4	0.006	0.068
5	0.045	0.053	5	0.028	2.123	5	0.028	0.568	5	0.031	1.913	5	0.028	0.398
6	0.083	0.327	6	0.051	2.581	6	0.050	0.637	6	0.052	2.842	6	0.050	0.478
7	0.120	0.585	7	0.074	3.199	7	0.073	0.845	7	0.074	3.880	7	0.072	0.729
8	0.158	1.021	8	0.095	3.869	8	0.096	1.221	8	0.096	4.884	8	0.094	1.025
9	0.195	1.912	9	0.119	4.647	9	0.118	1.727	9	0.116	5.829	9	0.116	1.390
10	0.232	3.108	10	0.140	5.526	10	0.141	2.248	10	0.137	6.923	10	0.138	1.878
11	0.268	4.290	11	0.162	6.547	11	0.164	2.796	11	0.159	8.039	11	0.160	2.435
12	0.305	5.763	12	0.185	7.683	12	0.185	3.369	12	0.179	9.212	12	0.181	2.989
13	0.340	7.495	13	0.205	8.664	13	0.208	3.893	13	0.200	10.451	13	0.203	3.579
14	0.377	9.320	14	0.228	9.676	14	0.230	4.425	14	0.221	11.642	14	0.225	4.185
15	0.412	11.300	15	0.250	10.555	15	0.252	4.971	15	0.242	12.954	15	0.246	4.896
16	0.449	13.365	16	0.270	11.303	16	0.273	5.612	16	0.264	14.332	16	0.268	5.742
17	0.484	15.467	17	0.293	12.072	17	0.295	6.284	17	0.284	15.812	17	0.289	6.637
18	0.520	17.471	18	0.314	12.687	18	0.316	6.977	18	0.305	17.456	18	0.311	7.578
19	0.555	19.252	19	0.334	13.436	19	0.339	7.676	19	0.326	19.038	19	0.332	8.545
20	0.590	21.398	20	0.356	14.342	20	0.359	8.556	20	0.347	20.784	20	0.353	9.475
21	0.627	23.598	21	0.378	15.264	21	0.381	9.536	21	0.367	22.541	21	0.374	10.397
22	0.663	25.431	22	0.399	16.247	22	0.403	10.462	22	0.388	24.252	22	0.396	11.274
23	0.698	27.164	23	0.421	17.238	23	0.424	11.343	23	0.408	26.111	23	0.417	12.213
24	0.733	28.975	24	0.442	18.262	24	0.446	12.304	24	0.429	27.895	24	0.439	13.232
25	0.768	30.789	25	0.463	19.512	25	0.467	13.296	25	0.449	29.680	25	0.459	14.464
26	0.804	32.982	26	0.485	20.923	26	0.489	14.305	26	0.471	31.595	26	0.481	15.944
27	0.839	35.382	27	0.506	22.445	27	0.511	15.276	27	0.491	33.381	27	0.502	17.457
28	0.874	37.680	28	0.528	24.065	28	0.532	16.231	28	0.512	35.288	28	0.522	18.898
29	0.911	39.992	29	0.549	25.633	29	0.554	17.272	29	0.534	37.091	29	0.543	20.394
30	0.945	42.206	30	0.570	27.281	30	0.576	18.570	30	0.554	38.868	30	0.565	21.886
31	0.980	44.413	31	0.591	28.902	31	0.597	19.981	31	0.576	40.707	31	0.587	23.379
32	1.016	46.614	32	0.613	30.497	32	0.618	21.444	32	0.596	42.415	32	0.608	24.852
33	1.051	48.753	33	0.635	32.203	33	0.640	22.901	33	0.617	44.129	33	0.629	26.311
34	1.086	50.940	34	0.655	33.751	34	0.662	24.329	34	0.637	45.920	34	0.650	27.755
35	1.122	53.143	35	0.677	35.366	35	0.684	25.772	35	0.658	47.577	35	0.671	29.251
36	1.157	55.309	36	0.699	37.050	36	0.704	27.164	36	0.679	49.338	36	0.692	30.679
37	1.192	57.533	37	0.720	38.658	37	0.726	28.548	37	0.699	51.041	37	0.713	32.195
38	1.228	59.733	38	0.742	40.334	38	0.747	29.930	38	0.720	52.663	38	0.734	33.714
39	1.263	61.959	39	0.763	41.950	39	0.769	31.281	39	0.741	54.417	39	0.755	35.280
40	1.298	64.143	40	0.784	43.552	40	0.790	32.649	40	0.761	56.067	40	0.776	36.813
41	1.332	66.298	41	0.806	45.280	41	0.812	33.993	41	0.782	57.745	41	0.797	38.373
42	1.367	68.530	42	0.826	46.831	42	0.834	35.325	42	0.803	59.565	42	0.81857	39.945
43	1.403	70.765	43	0.848	48.383	43	0.855	36.669	43	0.823	61.205	43	0.83966	41.564
44	1.438	73.012	44	0.870	50.042	44	0.877	37.966	44	0.844	62.998	44	0.86076	43.097
45	1.473	75.313	45	0.891	51.592	45	0.898	39.295	45	0.864	64.763	45	0.88186	44.697
46	1.507	77.597	46	0.913	53.196	46	0.920	40.648	46	0.885	66.471	46	0.90295	46.302
47	1.542	79.964	47	0.934	54.744	47	0.941	41.941	47	0.906	68.277	47	0.92405	47.914
48	1.578	82.348	48	0.956	56.248	48	0.963	43.285	48	0.926	70.027	48	0.94515	49.511
49	1.613	84.721	49	0.977	57.878	49	0.984	44.597	49	0.947	71.738	49	0.96624	51.124
50	1.648	87.118	50	0.998	59.350	50	1.007	45.899	50	0.969	73.534	50	0.98734	52.758
51	1.682	89.562	51	1.020	60.859	51	1.029	47.235	51	0.988	75.200	51	1.0084	54.407
52	1.718	91.963	52	1.041	62.428	52	1.050	48.535	52	1.009	76.919	52	1.0295	55.981
53	1.753	94.395	53	1.062	63.851	53	1.072	49.867	53	1.030	78.665	53	1.0498	57.616
54	1.788	96.753	54	1.083	65.339	54	1.093	51.170	54	1.050	80.281	54	1.0708	59.297
55	1.824	99.165	55	1.104	66.872	55	1.114	52.434	55	1.071	81.984	55	1.0921	60.982
56	1.859	101.550	56	1.126	68.302	56	1.135	53.746	56	1.092	83.629	56	1.1139	62.674
57	1.894	103.820	57	1.148	69.858	57	1.157	55.015	57	1.112	85.210	57	1.134	64.35
58	1.929	106.160	58	1.168	71.259	58	1.179	56.318	58	1.133	86.878	58	1.1553	66.064
59	1.965	108.400	59	1.189	72.697	59	1.200	57.628	59	1.153	88.432	59	1.1772	67.843
60	1.999	110.600	60	1.211	74.233	60	1.222	58.884	60	1.174	90.020	60	1.1975	69.513
61	2.034	112.850	61	1.232	75.701	61	1.243	60.192	61	1.194	91.611	61	1.2185	71.287
62	2.069	114.990	62	1.253	77.196	62	1.265	61.499	62	1.214	93.097	62	1.2396	73.104
63	2.105	117.090	63	1.274	78.792	63	1.285	62.780	63	1.236	94.648	63	1.2599	74.872
64	2.140	119.110	64	1.296	80.274	64	1.307	64.114	64	1.256	96.141	64	1.2812	76.673
65	2.174	121.050	65	1.317	81.886	65	1.328	65.432	65	1.276	97.595	65	1.3021	78.482
66	2.210	122.950	66	1.339	83.376	66	1.350	66.726	66	1.298	99.139	66	1.3232	80.314
67	2.244	124.740	67	1.359	84.875	67	1.372	68.061	67	1.317	100.540	67	1.3443	82.213
68	2.280	126.330	68	1.381	86.472	68	1.393	69.346	68	1.338	102.000	68	1.3646	83.999
69	2.315	127.990	69	1.403	87.975	69	1.415	70.654	69	1.359	103.440	69	1.3857	85.846
70	2.350	129.680	70	1.423	89.544	70	1.437	71.942	70	1.379	104.740	70	1.4067	87.741
71	2.386	131.390	71	1.445	91.132	71	1.458	73.175	71	1.400	106.140	71	1.4278	89.576
72	2.421	132.980	72	1.466	92.698	72	1.479	74.431	72	1.421	107.430	72	1.4481	91.457
73	2.456	134.370	73	1.488	94.376	73	1.501	75.694	73	1.441	108.690	73	1.4692	93.315
74	2.492	135.680	74	1.509	95.947	74	1.522	76.927	74	1.462	110.040	74	1.4903	95.198
			75	1.530	97.537	75	1.544	78.235	75	1.483	111.280	75	1.5114	97.078
			76	1.551	99.210	76	1.566	79.489	76	1.503	112.560	76	1.5316	98.948
			77	1.573	100.780	77	1.586	80.775	77	1.523	113.820	77	1.5527	100.84
			78	1.593	102.350	78	1.609	82.094	78	1.544	114.980	78	1.5738	102.72
			79	1.615	104.000	79	1.629	83.351	79	1.565	116.210	79	1.5949	104.57
			80	1.636	105.610	80	1.651	84.615	80	1.585	117.360	80	1.6154	106.43
			81	1.657	107.230	81	1.672	85.865	81	1.605	118.420	81	1.6371	108.34

			82	1.679	108.810	82	1.694	87.102	82	1.627	119.600	82	1.6574	110.24
			83	1.699	110.360	83	1.716	88.396	83	1.646	120.630	83	1.6793	112.19
			84	1.721	111.970	84	1.736	89.603	84	1.667	121.690	84	1.7004	114.09
			85	1.742	113.520	85	1.758	90.869	85	1.688	122.790	85	1.7206	115.92
			86	1.764	115.090	86	1.780	92.147	86	1.708	123.710	86	1.7417	117.8
			87	1.785	116.680	87	1.801	93.367	87	1.730	124.700	87	1.762	119.66
			88	1.806	118.200	88	1.822	94.567	88	1.750	125.660	88	1.7832	121.53
			89	1.828	119.830	89	1.845	95.775	89	1.770	126.580	89	1.8042	123.29
			90	1.849	121.340	90	1.865	96.934	90	1.791	127.520	90	1.8245	125.13
			91	1.870	122.840	91	1.887	98.195	91	1.812	128.340	91	1.8464	127.05
			92	1.891	124.400	92	1.909	99.408	92	1.832	129.250	92	1.8667	128.82
			93	1.913	125.890	93	1.930	100.660	93	1.853	130.110	93	1.8877	130.63
			94	1.934	127.360	94	1.952	101.930	94	1.873	130.810	94	1.9089	132.46
			95	1.956	128.910	95	1.973	103.140	95	1.893	131.620	95	1.9291	134.23
			96	1.976	130.340	96	1.995	104.400	96	1.915	132.370	96	1.9502	135.85
			97	1.998	131.790	97	2.016	105.640	97	1.935	133.040	97	1.9713	137.5
			98	2.019	133.170	98	2.038	106.880	98	1.955	133.870	98	1.9924	139.14
			99	2.039	134.510	99	2.060	108.160	99	1.976	134.580	99	2.0135	140.82
			100	2.061	135.910	100	2.080	109.390	100	1.997	135.330	100	2.0346	142.39
			101	2.082	137.210	101	2.102	110.660	101	2.017	136.120	101	2.0557	143.97
			102	2.104	138.460	102	2.123	111.930	102	2.037	136.850	102	2.0768	145.49
			103	2.125	139.780	103	2.144	113.170	103	2.058	137.690	103	2.0979	146.87
			104	2.146	140.980	104	2.166	114.420	104	2.079	138.440	104	2.119	147.98
			105	2.168	142.190	105	2.187	115.700	105	2.099	139.000	105	2.1401	149.19
			106	2.189	143.210	106	2.209	116.950	106	2.120	139.880	106	2.1612	150.25
						107	2.230	118.260	107	2.141	140.670			
						108	2.251	119.560	108	2.161	141.440			
						109	2.272	120.840	109	2.183	142.290			
						110	2.294	122.190	110	2.203	142.960			
						111	2.316	123.510	111	2.223	143.650			
						112	2.337	124.870	112	2.244	144.380			
						113	2.359	126.160	113	2.265	144.870			
						114	2.380	126.810	114	2.285	145.460			
									115	2.306	145.800			

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